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BRIQUETTED COAL AND ITS VALUE AS A RAILROAD FUEL.

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The conservation of our fuel resources, which has become a subject of active interest in past few years, is exemplified in the history of the briquetting industry as we follow its development in Europe and later in this country. We may naturally expect to find its inception in the countries where a thrifty people have learned to husband their resources and turned to good account their poor or depleted fuel supply. A country like ours, of such wonderful natural resources and so profligate in their use, does not offer the proper stimulus to an industry which depends upon trade conditions of high prices where close profits have forced economy in the small detail of saving.

Nomenclature.

The name "briquet," which is now universally used for all forms of compressed fuel, was applied originally in Paris to fuel made from peat with the addition of wet clay, similar to our present day methods of making wet clay bricks. The term was later made to include all fuel made by compression without the use of a binder in contradistinction to that made from bituminous and anthracite coal with pitch or other binders. We find numerous other names used, such as "boulet," "charbon agglomeres," or "houilles agglomeres," abbreviated to "agglomeres" in France; "briquettes de charbon" in Belgium; "patent fuel" and "compressed fuel" in England; "kohlensteine" or "kohlenzeiglen" in Germany, applied generally to briquets made from true coals with binder; while "artificial fuel" embraced all fuel manufactured from coal, lignite, peat or other form of combustible.

In America the word "briquet" has been accepted as a generic term for the product, while specific names such as "pressed fuel," "coalette" and "carbonet" are found in the trade. "Eggettes" are generally applied to briquets made on

*Class of 1897. Briquetting Engineer, Roberts & Schaefer Co., Chicago.

the so-called "Belgian roll" type of press, a name said to have been invented by Mr. Ware B. Gay for the product of a Loiseau press of this type. Fig. 1 shows samples of American made briquets.

Historical.

The earliest record on the briquetting of coal was suggested in a pamphlet by Sir Hugh Pratt in 1594. The first satisfactory briquetting machine was built in France in 1842 by M. Marsais, and since that time, the industry has gone steadily forward in all the European countries.

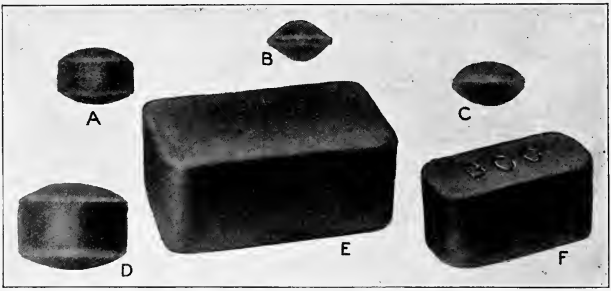

FIG. 1. SAMPLES OF BRIQUETS.

A. Briquet made by U. G. I. Co., Philadelphia.
B. Briquet made on Zwoyer press.
C. "Eggette" made by Solvay Process Co., Detroit.
D. "Carbonet" made at Hartshorne, Okla., plant.
E. Briquet made on Johnson press.
F. Briquet made by Briquette Coal Company.

The first briquetting plants were installed in England in 1846, Belgium in 1852 and Germany in 1861. About 1870, the briquetting of brown coals was first successfully accomplished in the last named country.

Prominence was given to the industry by the exhibits of briquetting machinery at the Paris Exhibition of 1867, and the following year we find the first recorded interest for coal briquetting in America. In 1870 E. F. Loiseau installed at Port Richmond, Philadelphia, the first coal briquetting plant. The press used was of Belgian type known as the "Loiseau rolls" and made eggettes weighing about eight ounces, using 92% anthracite culm and 8% clay

as a bond. These briquets were water-proofed with a varnish of shellac and benzine, but the cost was prohibitive. The plant was never a success, either mechanically or commercially, and was finally abandoned, but it marks the first step of the briquetting industry in this country and had its influence on the future, not without, we believe, beneficial results.

The Delaware and Hudson Canal Company built a similar plant at Rondout, in 1876, which was later absorbed by the Anthracite Fuel Company in 1878 and operated until 1880. This plant also briquetted anthracite screenings using pitch made from gas house tar as a binder. The third plant in the east to use the Loiseau roll press was built at Mauch Chunk, Pennsylvania, and was short lived. The binder in these briquets made a smoky fuel which disintegrated in the fire and was otherwise unsatisfactory.

The next important plant established in the United States was at Mahanoy City, Pennsylvania, in 1890, by the Anthracite Pressed Fuel Company. The plant was designed by the Uskside Engineering Company of Newport, England, using a Stevens press. The briquets were rectilinear with an eagle on one side and the word "Reading" on the other and weighed eighteen pounds. The plant had a capacity of 400 tons per day of ten hours. The dies were changed later to make two-pound briquets and the capacity reduced to 300 tons. The binder was pitch made from coke oven tar imported from England and 8% was used in making the briquets. The Philadelphia and Reading Railroad expected to save $50,000.00 a year in their fuel by means of this plant, but the briquets were not satisfactory owing to the high ash content of the culm and the excessive cost of binder. The plant failed in 1892 owing to a slump in the price of coal and inability to get sufficient quantities of binder, but it is noteworthy as marking the first important attempt to make briquets for railroad purposes.

In 1892 Mr. Ware B. Gay built a plant at Gayton, near Richmond, using one set of Loiseau rolls for the briquetting of Virginia semi-anthracite slack and using coal tar pitch as a binder. The capacity of this plant was doubled later. Similar plants were installed at this time at Milwaukee and Chicago for briquetting anthracite dust and bituminous slack made at transfer plants in these cities. In the dull coal season the Chicago plant made briquets of iron ore dust for the Illinois Steel Company.

A more pretentious plant was built in the same year at Huntington, Arkansas, under patents of M. Nirdlinger, controlled by the National Eggette Coal Company of New Jersey.

The Huntington plant made briquets of a mixture of Arkansas semi-anthracite and bituminous coals, using hard pitch and coal tar as a binder. These plants failed generally because of inexperience in preparing the coal which, as a rule, was too dirty; inability to get uniform pitch of the proper specifications; the expense of briquetting; and the cheapness of the coal with which the briquets must compete. These observations were made by Mr. Gay in referring to the Richmond plant, to which he added that "prismatic shape is less desirable than one affording better combustion by forming interstices between the pieces, especially when used for domestic purposes."

Recent American Plants.

We find the next development of the briquetting industry in California, where more actual progress has been made than in any other locality, although at the present time no plants are operating. The first plant was built at Stockton, California, to make briquets from lignite mined at Tesla. Bituminous screenings were mixed with the lignite and asphaltum residuum from the distillation of California petroleum used as a binder. The press was designed by Mr. Robert Schorr of San Francisco, and combined the continuous operation of the rotary type with the exactness and efficiency of the plunger press. Two presses were installed having a capacity of 125 tons per day of "boulets" weighing from 6 to 8 ounces. The Mammoth Oil Refining Company, a subsidiary enterprise, spent considerable money in developing a distillation plant for making briquetting pitch. The plant burned in 1905. These briquets were used on the San Francisco and San Joaquin Railway and made a satisfactory locomotive fuel, eliminating the objectionable features of raw lignite.

Another Schorr press was installed at Oakland, California, by the Western Fuel Company for briquetting the accumulations of slack coal on its docks. The operations of this plant were discontinued at the time of the earthquake when the price of pitch became prohibitive.

A briquet press of novel design was built by Mr. C. R. Allen and installed at Pittsburg, Calif., for the briquetting of lignite mined at Somersville. This press was on the order of the roll type, making a cylindrical briquet weighing 8 to 10 ounces. The plant had a capacity of 5 tons per hour using asphaltic pitch as a binder.

The Standard Coal Briquetting Company of Oakland and the American Briquetting Company of San Francisco made unsuccessful attempts to produce commercial briquets, which

failed on account of economic conditions already mentioned. The latter plant experimented with Coos Bay lignite mixed with coal yard screenings.

The Arizona Copper Company, Clifton, Arizona, is making briquets for its own use, from the slack of sub-bituminous coal mined at Gallup, N. M. A Yeadon press built in England is used, making four-pound briquets of prismatic shape at the rate of about 2½ tons per hour. Asphaltic pitch is used as a binder. The economic value is found in the storing qualities of the fuel made from a slack that will either "fire" or at least deteriorate rapidly when stored. Coke breeze, hitherto wasted, has also been mixed with the slack coal.

The Washington Coal Briquetting Company of Seattle has built a plant using a plunger type press designed by Mr. Henry Mould of Pittsburg, constructed along the lines of his press for briquetting flue dust and ores. This plant was completed in 1908, but up to date has not made a commercial product. It was designed to utilize the slack from low-grade fuels sold for domestic purposes in Seattle. A press of the Couffinhal type, built by the Coal Briquette Machine Company of Oshkosh, Wis., has been installed at Sheboygan to briquet anthracite dust from the coal yards. This plant, installed in 1907, has not yet been put in commercial operation. The briquets are cylindrical and weigh about 12 ounces. The press has a capacity of 4 tons per hour.

The National Pressed Fuel Company has installed a press and plant designed by George W. Ladley and sold a limited amount of briquets in Indianapolis last winter to domestic trade. The press is an adaptation of the Brogneaux rotary type, and belongs to the same class as the Schorr press, combining the rotary and reciprocating types. It has a capacity of 12 tons per hour of 6-ounce briquets, cylindrical in shape, made from southern Indiana screenings and hard coal tar pitch. About 8% of binder is used.

The National Fuel Briquette Machinery Company has a small plant at the foot of Court St., Brooklyn, for demonstrating the Devillers press. The press is of the Belgian rolls type, has a capacity of 5 tons per hour, and makes an eggette weighing about 2 ounces out of small-sized anthracite and coal tar pitch, imported from Europe. The briquets are sold for domestic purposes. One of these presses was purchased a few years ago by the Consolidated Gas Company of New York to make briquets from coke breeze, but the product has not yet been marketed.

The Zwoyer Fuel Company of New York is one of the

pioneers of briquetting in this country and has developed an efficient press of the Loiseau type having a maximum capacity of 15 tons per hour of 2-ounce briquets. The briquets are pillow shaped, that is, rectangular in plan, but ovoid in both cross sections. This shape is a development on the one advocated by Hutteman and Spiecker and is designed to economize the effective area of the rolls and reduce the amount of waste in briquetting. Several plants have been built by this company in and about New York, in the past ten years, marking the perfection of their press and other equipment. At the present time the only operating plant is at Perth Amboy, owned by the New Jersey Briquetting Company. The product is loaded mechanically in barges direct from the storage bins at the plant, and sold in New York and Brooklyn in competition with stove sizes of anthracite. The briquets are made from anthracite screenings with 10% of hard coal tar pitch as a binder. The most important plant using the Zwoyer press and process is at Bankhead, Alberta, Canada, at the breaker of the Bankhead Mines, Ltd. This plant has been operating since 1906 and has recently doubled its capacity, making during March, 1909, over 15,000 tons of briquets. The coal used is a friable semi-anthracite, and about 10% of coal tar pitch is used as a binder. The output is sold principally for domestic purposes and shipped as far east as Winnipeg.

A press of similar design is manufactured by the Mashek Engineering Company of New York. One of these presses is installed at a plant of the D. Grieme Coal Company, West 27th Street, New York, making briquets of anthracite buckwheat and coal tar pitch binder.

The United Gas Improvement Company of Philadelphia and the Solvay Process Company of Detroit have done considerable work in developing the briquet industry, as a means of disposing of their by-products and not primarily to market briquets. The United Gas Improvement Company purchased and installed in 1905 a rotary press manufactured by the Societe Nouvelle des Etablissements de L'Horme et de La Buire, Lyon, France, and are making an eggette weighing 5 ounces. As the plant now stands they have the original press and one of this type adapted to American conditions, making a pillow-shaped briquet weighing 2 ounces. The presses have a capacity of 5 tons per hour. Anthracite buckwheat and smaller sizes are made with 10% water gas pitch into briquets used exclusively for making water gas, and giving better results than the larger sizes of anthracite.

The Solvay plant has passed through a longer experimental

period beginning in 1904 with the installation of a Johnson press similar to that used at the St. Louis plant of the government. This press originally made 8-pound prismatic briquets; the dies were changed to make briquets weighing 4 ounces, but the troubles incident to feeding the dies and the reduced output led the company to abandon that press and substitute one built by Mr. Mashek, which did not prove satisfactory. The company has recently installed a press similar to the one at Point Breeze, made under the U. G. I. specifications, but making 2-ounce eggettes. These briquets contain coke breeze, Pocahontas slack and 8% hard pitch made from coke oven

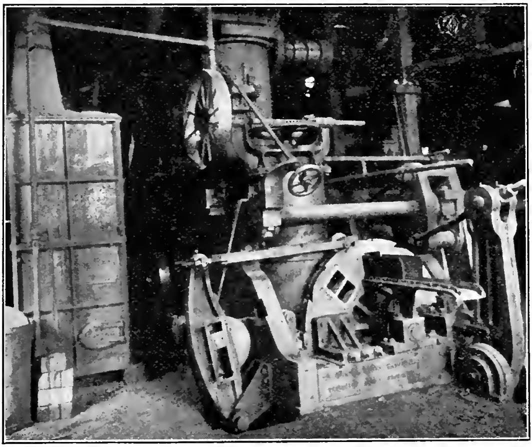

Fig. 2. Johnson press at Government Coal Testing Plant, St. Louis, Mo.

tar, and the company is now experimenting with a process to eliminate the smoke by partially coking the briquets.

The Briquette Coal Company had an experimental plant on Staten Island. A Couffinhal type of press, built by Schuchtermann & Kremer, Dortmund, Germany, making 4 tons per hour of 1½-pound rectilinear briquettes, was installed together with a Belgian press made by H. Stevens of Charleroi, making 5-ounce eggettes at about 7 tons per hour. The plant was never designed to operate commercially and has recently been abandoned. The equipment is being installed in a plant near the mines at Murphysboro, Ill., to make briquets under con-

tract with the St. Louis and Big Muddy Coal & Iron Company.

The work of the United States Geological Survey at St. Louis is fully described in government bulletins and need only be mentioned here. During the exposition period a Johnson press made at Leeds, England, was installed, together with the other equipment to make up a complete briquetting plant. This press made 8-pound briquets and had a capacity of 7 to 8 tons per hour. A White press of the Belgian or Loiseau roll type was also installed, but returned to the owners at the close of the exposition. After the writer was placed in charge of the plant, March, 1905, the die plate of the Johnson press, shown in Fig. 2, was reduced to one-half its original thickness and other improvements were made in order to briquet larger samples of coal, such as were subsequently used in the locomotive road tests discussed further on. In rebuilding the plant in February, 1906, the first operating press of the Renfrow Briquette Machine Co. of St. Louis was installed, making a briquet weighing approximately 8 ounces at the rate of 6 to 7 tons per hour. While this press embodied all the fundamental principles of later presses, it could only be considered an experimental press, and briquets made were far from satisfactory. The same difficulties were experienced as may be found in the history of all briquetting presses in this country and abroad. Insufficient pressure frequently made soft briquets and required an excess of binder with a low melting point.

Profiting by this experience, the Renfrow Company built a new press having a capacity of 8 to 9 tons per hour, and making a briquet of the same shape weighing 13 ounces. This press was installed at the Norfolk plant of the Survey and made the briquets tested on the eastern railroads and for the Navy Department. Upon concluding the Norfolk tests the machine was sold to the Rock Island Coal Mining Company and installed by the writer at Hartshorne, Okla. (See Fig. 3). The plant has been operating since August, 1908, part of the time on double shift, briquetting the bituminous slack mined by the company and marketing the product for domestic purposes in Oklahoma, Arkansas and Texas under the trade name of "Carbonets." This may be said to be the first plant in the Middle West to be put on a successful commercial basis. The success of the undertaking is largely due to the careful consideration of the problems involved in the mechanical construction of the plant, the binder used and the market conditions encountered.

The Western Coalette Fuel Company of Kansas City, who used a Renfrow press, were unsuccessful because these problems were not given sufficient consideration. A still later press

of the Renfrow Company has been installed by the Detroit Coalette Fuel Company to make briquets from Pocahontas coal for domestic purposes. This plant was completed in the summer of 1909.

Kansas City is being supplied again this winter with briquets by the Standard Briquette Fuel Company of St. Louis; the plant was designed and built at Kansas City by the Roberts and Schaefer Company of Chicago, using a Misner press. This press is of the plunger type having a capacity of ten tons per

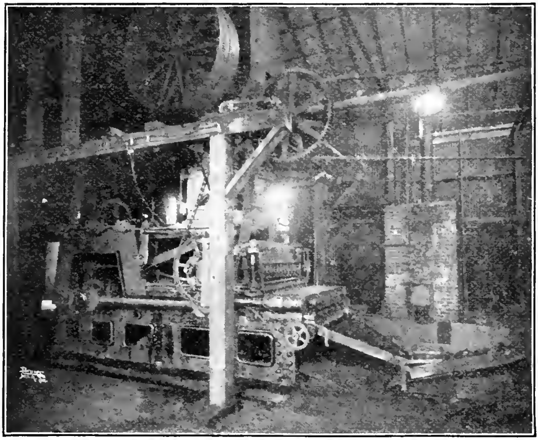

Fig. 3. Renfrow press making "Carbonets" at the briquetting plant of the Rock Island Coal Mining Co., Hartshorne, Okla.

hour. Arkansas semi-anthracite and hard coke oven pitch will be used. The briquets will be cylindrical with spherical ends and average 14 ounces in weight.

Of the presses so far available, the maximum output has been about ten tons—with the possible exception of the Zwoyer press—in making briquets of 4 pounds and less in weight. If we eliminate the binder, the cost of production varies directly with the output. The speed of reciprocating press of the Couffinhal type is fixed by the time required to move the die plate. Rotary presses, of the Loiseau type, do not make satisfactory briquets larger than 5 to 6 ounces. Experience has shown that

for railroad fuel made from bituminous coal, briquets of from 2 to 4 pounds each give best results. It is encouraging to learn that there is being tested, at an Illinois mine near St. Louis, a briquet machine which is a new departure from anything so far exploited in this country, bearing some relation to the one manufactured by Flaud et Cie of Paris. The dies are filled with the same accuracy as in the Renfrow and other plunger presses, and the compression is made by the positive action of plungers with a straight line motion, but there are no reciprocating parts, and in consequence no lost motion. This press has a capacity of from 25 to 50 tons per hour, and is capable of making briquets from 2 ounces to 20 pounds in weight by changing the dies.

No effort has been made in this article to discuss plants and briquets other than those using anthracite or bituminous coal.

An excellent study of the treatment of Texas lignites has been given by E. T. Dumble in a "Report on the Brown Coals and Lignite of Texas," in which he states the earliest efforts at briquetting were made by the Houston and Texas Central Railway in 1877. The International Compress Company, the American Lignite Briquette Company and the Eureka Briquette Company of Texas, have been exploiting the briquetting of lignite with binders, while the Washburn Lignite Coal Company and the Northwestern Briquet Manufacturing Company of Minneapolis have been experimenting with the briquetting of lignite without a binder.

Manufacturing Process and Binders.

The briquets which we shall consider are made by pulverizing the coal, already of the proper dryness, adding a binder, mixing the mass thoroughly with the addition of sufficient steam to melt or moisten the binder and moulding the agglomerate in specially constructed presses.

In the briquetting process, the most expensive item of cost is the binder, and every conceivable substance or mixture having bonding properties has been proposed for this purpose. Refuse containing starch and sugar, sulphite liquor, clay and lime are among the best known. Binders soluble in water must be water-proofed and dried before being handled, a process, which is usually so expensive as to be prohibitive. The inorganic binders are objectionable on account of the additional ash and clinker added to the fuel. Deodorants in the form of compounds of chlorine are recommended to overcome the odor from pitch and sulphur during combustion and to reduce smoke, but their value is doubtful. Com-

pounds of manganese and other highly oxygenated compounds are recommended as smoke preventives, where coal tar pitch is the binder. But, except in special instances, pitch alone is used which is made from tar recovered as a by-product in the destructive distillation of coal, from by-product coke ovens, or in carburetting water gas for illuminating purposes.

Since the binder is of such importance, it is essential that the amount be reduced to a minimum and that it be thoroughly mixed with the coal. In American practice, the percentage of pitch required varies from 5 to 10%, according to the process used and the coal to be briquetted. An accuracy within one per cent, more or less, seems reasonable from a mechanical standpoint, but should 8% be the amount of binder used normally, it means 12%, more or less, in the cost, which is of economic importance.

Briquetting Pitch.

In the fractional distillation of coal tar, a recovery of 65% pitch with 1.19 specific gravity is a fair average. On account of the varying demands for by-product coke oven tar in Europe, the quality is constantly changing at the different works. In this country the lack of uniform methods and the great variety of coals and oil used present the same difficulties in obtaining a uniform product. Briquetting pitch should be hard enough to be shipped in bulk in open cars and remain hard on the hottest days. To effect this all of the lighter oils and about 5% of the anthracene should be extracted. In Europe the pitch becomes soft at 75° and melts at from 100° to 120° C. As pitch has no real melting point, the methods used in fixing a melting point are arbitrary. Following the methods established by the Government, and in use here, practice has shown that a pitch with a melting point of 90° C. meets the general requirements. Pitch should also contain as little free carbon as possible, since this carbon or fine dust has not only no binding property in itself but requires a bond to hold it together in the briquet. In the distillation of coal, carried on primarily for the manufacture of gas or coke, or both, the time factor in the process determines the character of the tar produced as a by-product. High heats "crack" the higher hydrocarbons during the distillation, producing finely divided free carbon which remains in suspension in the tar. This condition is also maintained during the distillation of the tar in making pitch. Briquets made with the hard pitch usually sold in America today, are brittle and produce considerable slack in handling. If a softer grade is used, the briquets are

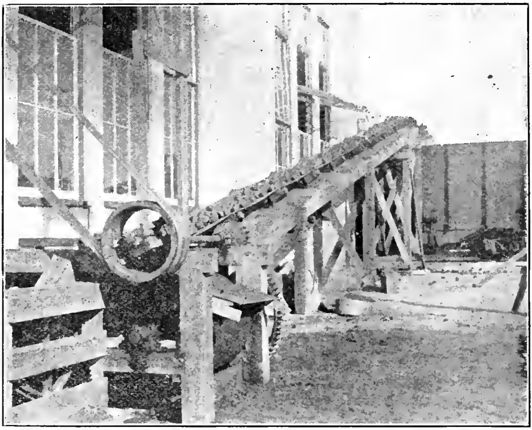

Fig. 4. Loading briquets direct from machine to car, Government Coal Testing Plant, Norfolk, Va. Briquets made from Pocahontas coal and tested on U. S. S. Connecticut.

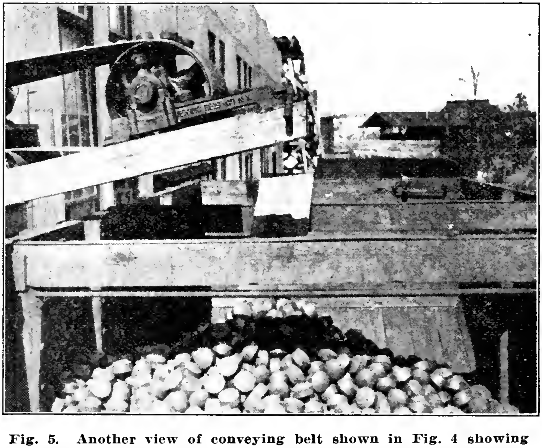

Fig. 5. Another view of conveying belt shown in Fig. 4 showing how briquets can be loaded mechanically without breakage.

smoky, and have a disastrous effect on the faces and hands of the workmen. To overcome these difficulties, experiments were carried on at the Stockton plant and a binder produced from California petroleum that was both hard and tough. The Barrett Manufacturing Company has for some time recognized the importance of a satisfactory "briquetting pitch" and is now prepared to market a product following specifications already suggested by the writer.

Handling and Breakage.

One of the principal problems which confronts producers and users of coal, and particularly the railroads, is the deterioration of its fuel in handling and storing. Bituminous coal cannot be handled without breakage, which assumes a very considerable percentage even in well designed coaling stations. This is more noticeable in the friable, low volatile coals. English statistics show that with Welsh bunker coal the waste in handling is 2 to 3%, and the breakage 20 to 30%, which aften reaches 50% in rough weather. The cohesion of briquets made in South Wales show 83%, against 40% for the same coal in lump form for which the breakage was .88% for briquets and 2.13% for coal. It has been observed by a mechanical engineer of a western railroad that the percentage of dust in handling briquets three times should not exceed 8%.

Figs. 4 and 5 show the manner of handling briquets direct from machine to car, and the absence of slack in the car is apparent. Fig. 6 shows a carload of briquets made from Pocahontas coal being delivered to a navy barge at Norfolk. Fig. 7 is from a photograph taken thirty seconds after the one shown in Fig. 6, and is further evidence of the small amount of breakage which we may expect from well-made briquets. The drop from bottom of car to deck of barge is about 15 feet. These pictures further illustrate the rapidity with which this form of fuel may be handled in coaling stations. It requires about 20 minutes to unload a similar self-clearing car of coal at the Norfolk and Western coaling piers at Lambert's Point, an item of considerable importance in bunkering a ship.

In all locomotive tests, referred to later, where the briquets were reasonably well made, the breakage in handling was negligible; and the results of other tests made at the St. Louis plant bear out the European experience. The percentage of slack in handling was approximated by a series of experiments known as "drop tests," in which 50 pounds of briquets were three times dropped a distance of 6½ feet on a cast-iron plate, and the percentage of broken briquets recorded which was

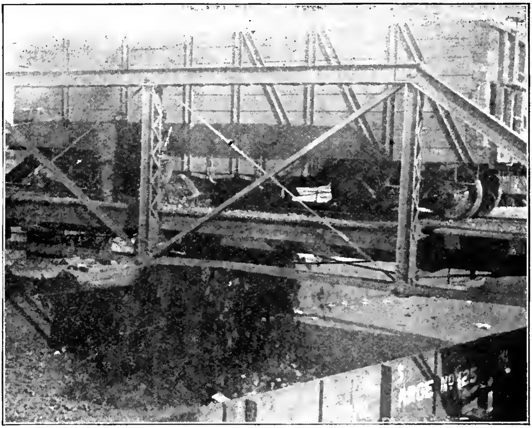

Fig. 6. Briquets being loaded on Government barge at Norfolk for test on U. S. S. Connecticut. This photograph was taken as hoppers were opened.

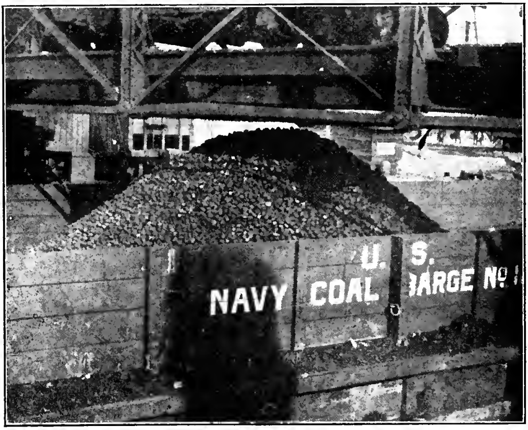

Fig. 7. View taken 30 seconds later than that shown in Fig. 6, showing rapidity with which this form of briquet can be discharged from hoppered bottom cars and without breakage. It takes 20 minutes to unload lump coal from same car.

retained on a 1-inch square mesh wire screen. These results were used to check the tumbler tests, similar to those made in Europe to determine the cohesion of the briquet. Fig. 8 shows the relative cohesion of briquets, coke and lump coal after being subjected to the tumbler tests. It was found that the constant jarring of the fuel on locomotive tanks created considerable slack when the briquets were badly made. The tumbler tests approximated the results obtained in practice. If the briquets were well made, the cohesion was greater and the erosion less than with the same coal in lump form. Breakage not only produces a poorer locomotive fuel but increases the losses due to wastage or otherwise unaccounted for.

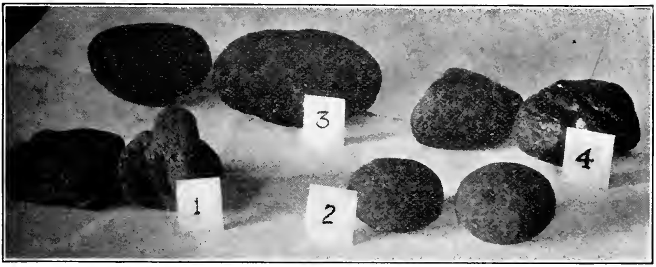

Fig. 8. Showing the relative cohesion of briquets, coke and lump coal, after having been subjected to the tumbler test.

No. 1. West Virginia coke.
No. 2. Round briquet made of Arkansas coal.
No. 3. Square briquet made of Arkansas coal.
No. 4. Southern Illinois lump coal.

Storage.

In countries where labor is cheap, large prismatic briquets are used because they can be easily stacked by hand, and occupy less bunker space. For this reason the French Navy specifies large briquets with an estimated bunker capacity of 51 pounds per cubic foot or 10% less than for coal. With the increased calorific value this is of supreme importance by increasing the steaming radius of the vessel. The British Admiralty reports 20% increased steaming radius. The briquets in this form, however, require twice as long to coal as with the raw fuel. In India and the West Indies 28-pound briquets are used because one constitutes a load for a native. It was shown at the government tests at Norfolk that as much as

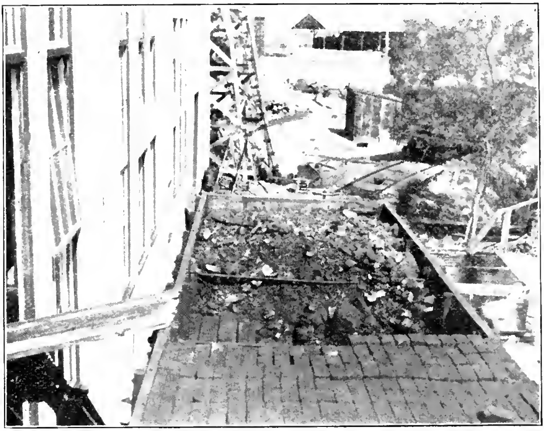

Fig. 9. This car was originally full of coal, approximately one-half of which was taken out, briquetted with 6 per cent binder and returned to car. This illustration shows the reduced bunker capacity required by briquets.

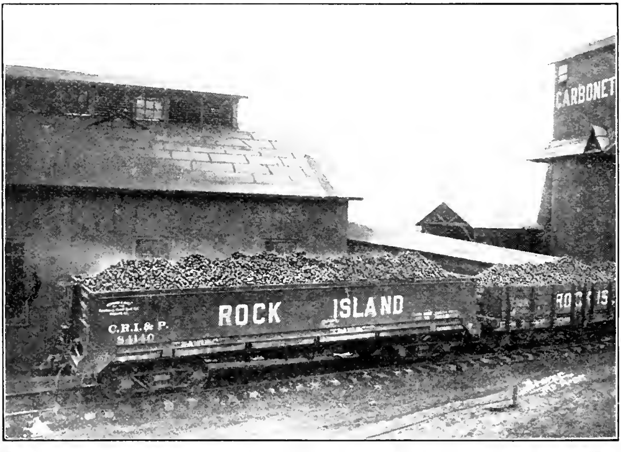

Fig 10. Carload of "Carbonets" at Hartshorne, Okla.

20% increased space was required when prismatic briquets were loaded without stacking. Fig. 9 illustrates the reduced bunker capacity of briquets over that required for coal. This car originally contained a maximum load of coal, approximately one-half of which was briquetted and returned to the car. The briquets made at the Hartshorne plant loaded to capacity on gondola or dump cars will weigh within 10 to

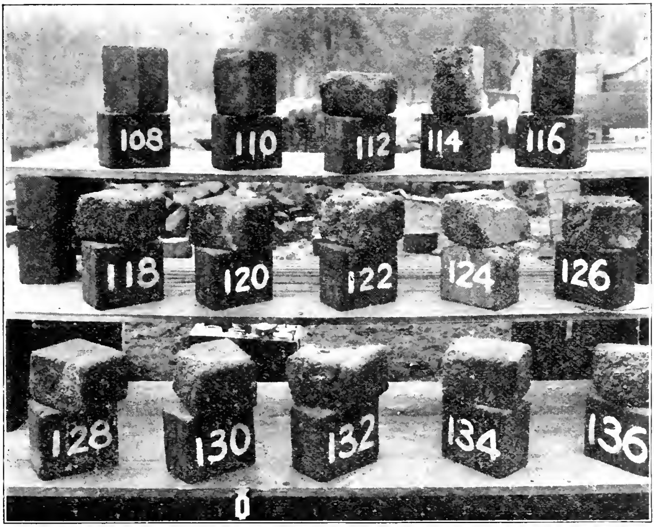

Fig. 11. Samples of briquets taken from open storage piles at the Government Fuel Testing Plant, St. Louis, after 3 years' exposure. In each sample one briquet was taken from surface and interior of pile to show effect of weathering. In sample 108, 110, 118, 120 and 128 the briquets were made with coal tar pitch binder. These briquets were made on the Johnson press during 1904 and weigh 8 pounds.

15% as heavy as mine run coal, or about equal to egg size, as shown in Fig 10. No difficulty was experienced in loading box cars to capacity plus 10%.

Weathering.

It has been observed that carefully executed tests in Europe show nearly 30% of the heating value of coal is lost when stored in open piles, while English naval records have

Fig. 12. Briquets made from Pennsylvania coal after three months' open storage. The broken briquets show the character of fracture.

Fig. 13. Briquets made from raw Kansas slack after three months' storage in the open during the winter. This slack is high in sulphur and cannot be stored without "firing."

mentioned that it required from 50 to 100% more stored coal to operate vessels than when freshly mined coal is used.

Experiments made in this country show that about 10% depreciation may be expected from coal stored in the open and that housing only helps the situation where the coals are high in sulphur.

Fig. 11 represents samples of briquets taken from open storage piles at the Government Fuel Testing Plant, St. Louis, after three years' exposure. In each sample a briquet was taken from surface and interior of pile to show effect of weathering. In samples 108, 110, 118, 120 and 128 the briquets were made with coal tar pitch binder. These briquets were made on the Johnson press during 1904 and weigh 8 pounds. Analyses of these samples show practically no loss in calorific value. In Fig. 12 one of the outer briquets was broken to show the character of the fracture. These briquets show no deterioration after three months' storage in open pile. The briquets shown in Fig. 13 were made from a high sulphur coal that cannot be stored without igniting from spontaneous combustion, particularly if exposed to the weather.

Mr. W. H. V. Rosing, mechanical engineer of the Missouri Pacific Railway, states that "it is our practice to store coal during the summer months when the coal cars on the system are not being fully utilized, and use coal from storage piles later in the season when all the cars are required for commercial use. In this manner several hundred thousand tons are stored annually. During the summer of 1907 we lost 14,400 tons of coal by spontaneous combustion alone, which amounted to 8½% of the total stored. In fact we can only store coal from certain mines on the system, and this must be stored in a certain manner to avoid loss by spontaneous combustion. With the briquetted fuel we could store coal from any of the mines without danger of spontaneous combustion, without deterioration or loss of volatile combustibles which occurs on the surface of the ordinary coal piles."

Mr. A. W. Gibbs, G. S. M. P., Pennsylvania Railroad, makes the following statement in his report of briquet tests at Altoona:

"To observe the effect on briquets of exposure to the weather a number of the round and square briquets were placed on the roof of the testing plant. After four months of exposure for the round and three months for the square briquets no change whatever from their original condition was noticed. They appeared to be entirely impervious to moisture and were still firm and hard.

"The briquets were little affected by handling. They were loaded at St. Louis in open gondola cars and shipped to Altoona, where they were unloaded by hand and stacked. They were handled a third time in taking them to the firing platform of the test locomotive. After these three handlings they were still in good condition, very few were broken, and the amount of dust and small particles was practically negligible."

Briquets Used on European Railroads.

Practically all of the European railroads use briquets and the quantity varies from 15 to 40% of the total coal consumed. The briquets for railway and steamship use are prismatic in shape. The French navy specifies 22-pound briquets. These briquets are broken before firing, and if well made will break into pieces without making dust. The railroads use briquets not to exceed 11 pounds in weight, which are fired one or more at a time by hand. Storage fuel is usually in the form of briquets; they are carried on the tanks along with coal and generally used to get up steam, to make up time, or over heavy grades during the run.

The specifications to contractors furnishing briquets to the state railroads on the continent are very rigid, particularly in France. These specifications vary somewhat in the different countries but are covered generally by the following items:

1st. Briquets shall be well made, sonorous, entire, with sharp edges, breaking with a clean cut, brilliant and homogeneous fracture.

2d. Their cohesion shall not be less than 55% and they shall not soften at 50° C.

3d. The briquets shall ignite easily without causing dense black smoke, shall burn with a quick bright flame and be consumed without disintegrating. The slag or clinker shall not adhere to the grates or tube sheets.

4th. The briquets shall not be hygroscopic nor contain more than 4% moisture. They shall contain between 15 and 22% volatile combustible, and not more than 11% ash. The coal shall have been freshly mined and free from sulphur.

5th. Coal tar pitch is the only binder specified; it must be practically odorless and limited to 10%.

6th. The briquets must be prismatic with a square base; when specified they are from 3 to 11 pounds in weight, according to kind of coal used, with a density of from 1.13 to 1.21.

Work of Government Plant at St. Louis.

During 1905, 1906 and 1907, over one hundred tests* were

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conducted by the government on eastern and western railroads to establish the relative value of briquetted and raw coal for locomotive use. Seventy road tests were made on the Burlington, Rock Island, Missouri Pacific and Chicago & Eastern Illinois Railways, and twenty tests at the Altoona laboratory of the Pennsylvania Railroad, under the direction of the writer, assisted by G. E. Ryder and Ralph Galt. The co-operation of all the railroad officials was secured so that these tests would be of value to them in comparison with other locomotive fuel tests. An abridgment of Mr. E. D. Nelson's report on the Pennsylvania laboratory tests has been published in Bulletin No. 363 of the Survey.

The briquets were made at the Fuel Testing plant at St. Louis, and the details of manufacture have already been reported in Bulletin No. 332 of the U. S. Geological Survey. The object of the road tests was to discover, if possible, the problems to be encountered in the use of briquets in actual practice and wherein this practice was affected by good or faulty manufacture of the fuel. It must be remembered that the best efforts at the St. Louis plant could not produce uniformly satisfactory briquets. The English machine was designed to meet European requirements and the American machine was in an experimental stage and made at best a product of varying quality. The problems involved in the manufacture of briquets from our coals have been already reported. It is one object of this article to show their value for railroad use.

Locomotive Road Tests.

The first locomotive tests were made during the autumn of 1905 on locomotives of the Missouri Pacific Railroad between St. Louis and Sedalia, after having tested the burning quality of the briquets in stationary locomotive boilers. The briquets were made on the Johnson machine from Arkansas semi-anthracite slack, and were tested in comparison with the Illinois lump coal regularly furnished for that division. The results given in a report by W. H. V. Rosing indicate an increased evaporation of 23% and a decreased consumption of fuel per 1,000 ton miles of 37% in favor of the briquets. The briquets were broken in halves on this test, which created about 20% slack.

About this time, the New York Central Lines became interested in the use of briquetted coke breeze, and burned some briquets made at the plant on the same machine. These briquets were tested in freight and switching service by the Lake Shore Railroad near Cleveland. The report of Mr. H. F. Ball, Superintendent of Motive Power, indicates that the

Fig. 14. Shows two suburban trains on the Rock Island passing each other in the yards north of Englewood. The locomotive to the right is burning briquets.

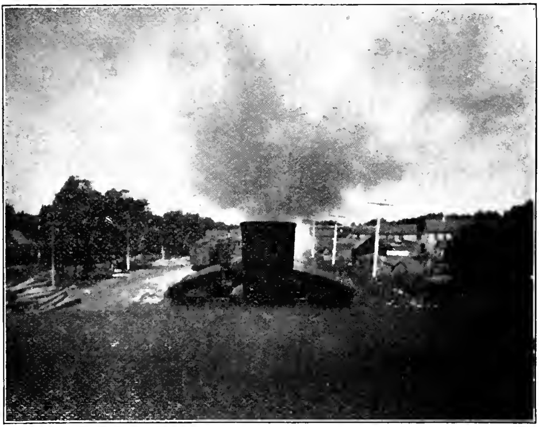

Fig. 15. Illustrates the characteristic puff of smoke lasting 3 to 5 seconds which appears directly after firing.

briquets were not satisfactory for heavy service, but had some advantages for switching, owing to the entire absence of black or gray smoke and very few cinders. The briquets were hard to ignite, which, added to the high ash content of the coke, and the size of the briquets, made it difficult to maintain a good fire.

Briquets made from mixtures of gas-house coke and Illinois screenings were tested in switching service by the Missouri Pacific Railroad at St. Louis. The briquets gave better results than the ones made from coke oven breeze. Even with those containing 50% coal, however, there was always an interval of time directly after firing when the steam pressure would fall. If the engine was working this was objectionable. No smoke was discernible even when the blower was shut off.

In June, 1906, the Rock Island Railroad became interested in the use of briquets and 100 tons of Hartshorne, I. T., slack were briquetted and shipped to Chicago for test. The report of C. A. Seley compared these results with Illinois lump coal used in freight service and indicated an average in the coal consumption of 26.2% in favor of briquets. The observer's notes on these tests state that "the briquets did not 'honeycomb' the tube sheets sufficiently to give any trouble and this slag was not as hard to remove as with Illinois coal. The ashes from the briquets did not clinker. The nozzle could be increased ¼ inch and still produce a sufficient draft. This fuel burns with an intense heat, much like coke, and the depth of the fire is easily regulated. On arriving at Joliet, an inspection showed fire next to the grate which would not be the case with coal. A slight puff of black smoke appeared only when briquets were fired; this almost immediately disappeared —a desirable feature for suburban service."

Fig. 14 shows two suburban trains on the Chicago, Rock Island and Pacific Railway passing each other in the yards north of Englewood. They are both running at full speed. The approaching train is burning coal.

Fig. 15 illustrates the characteristic puff of smoke which appears directly after firing briquets and lasts three to five seconds; engine is on Chicago, Rock Island & Pacific suburban service approaching Morgan Park at full speed. Fig. 16 shows engine standing at Walden, blower off; and Fig. 17 shows engine approaching Tracy at full speed.

The general interest awakened by these preliminary tests warranted the government in making more extensive records, and the co-operation of the Rock Island, Missouri Pacific, Burlington and Chicago & Eastern Illinois Railroads was sought to

Fig. 16. Shows Rock Island suburban engine standing at Walden with blower shut off.

Fig. 17. Shows engine of same train approaching Tracy at full speed.

this end. The samples, varying in weight from 100 to 400 tons, were shipped to St. Louis and briquetted on the English and Renfrow machine in about equal amounts, using from 6 to 9% of water gas pitch binder. The briquets were consigned to the railroad and loaded through its coal chutes in the usual manner in which coal is handled. Where the briquets were soft, care was taken to handle them with coke forks in weighing onto the tender. The water tanks were calibrated and the water measured as used. Flue gas analyses and front end and furnace temperatures were taken during the run. Careful selected samples of fuel, ash and cinders were shipped to St. Louis and anaylzed. Steam pressure, feed water temperature, leakage, smoke, condition and thickness of fuel bed, method of firing and draft were recorded. The same engine, and, as nearly as possible, the same crew were furnished by the railroad for all tests on that road. At the end of the run the condition of the engine was noted, and the test written up.

Comparative tests were made on lump coal from the same mines as the slack shipped from Oklahoma, Kansas and Missouri. A condensed summary of the results of these tests is given below. A record of tests on Carterville lump and mine run coal made by the Burlington Railroad is included for comparison with the tests of briquetted slack from the same district.

The foregoing report is condensed from a data sheet in which a total of 122 observed and calculated items made up the record of each test. Averages of all tests made on each kind of fuel are given, as for obvious reasons it is desirable to abridge the report. Noting the equivalent evaporation per pound of fuel as fired, it will be observed that in nearly all cases the rate is in favor of briquets.

In the case of the tests of Illinois coal on the Burlington Railroad, all of the fuels are from different mines and are therefore of comparative value only when their cost is taken into account. Tests of Illinois coal on the Missouri Pacific Railroad are omitted because of no comparative tests on lump coal. The Burlington tests with Missouri coal show practically the same results with briquets and lump coal, while the Indiana coals offer the same problems in briquetting and show the same characteristics in burning as Illinois coals.

The most representative tests, and therefore the most accurate expression of what may be accomplished with well made briquets, are the tests made on the Rock Island and Missouri Pacific Railroad with Oklahoma and Kansas coals. The Rock Island tests show an increase equivalent evaporation of 8% and increased boiler efficiency of about 15%, while the

LOCOMOTIVE ROAD TESTS SHOWING COMPARATIVE VALUES OF BRIQUETTED AND RAW COAL.

RAILROAD	C., B. & Q. R. R.				C., R. I. & P. RY.		MISSOURI PACIFIC RY.			C. & E. I. R. R.		C., B. & Q. R. R.	
COAL SHIPPED FOR TEST	CARTERVILLE DISTRICT, ILL.				HARTSHORNE, OKLAHOMA		PITTSBURG, KANSAS			SULLIVAN CO., INDIANA		BEVIER, MISSOURI	
	BRIQUETS		COAL		BRIQUETS	COAL	BRIQUETTS		COAL	BRIQUETS	MINE RUN	BRIQUETS	COAL
FUEL TESTED	Washed Ill. 28A	Un-washed Ill. 28B	3" Lump	Mine Run	Un-washed I. T. 2B	Lump I. T. 2C	Washed Kan. 2B	Un-washed Kan. 2C	Lump Kan. 7	Ind. 1B 5B 6B	Ind. 1B 5B	Mo. 10	¾" Lump
Proximate Analyses Fuel as fired: Moisture	5.67	5.41	5.59	4.70	2.1	2.54	3.44	2.49	5.47	7.14	13.86	7.69	11.40
Volatile Combustible	31.09	31.86	32.67	35.04	35.65	36.98	33.21	31.15	29.15	36.02	32.18	32.86	33.55
Fixed Carbon	50.75	51.38	52.80	47.14	50.74	53.97	52.45	47.33	49.81	44.18	41.90	39.52	42.12
Ash	12.49	11.35	8.94	13.12	11.51	6.51	10.9	19.03	15.57	12.66	12.06	19.93	13.93
Sulphur	1.11	1.87	....	....	1.63	1.75	3.67	4.43	4.8	3.63	3.48	4.50	5.78
B. T. U. per pound fuel as fired	11969	12163	....	....	13015	13681	13033	11713	11422	11711	10553	10429	10556
Fuel consumed per sq. ft., G. S. per hour actual	73.7	73.2	80.9	85.7	44.3	55.2	75.	78.2	92.1	48.	53.	71.	63.
Water evaporated per pound fuel: Apparent, Actual	7.25	6.95	7.56	6.86	7.60	7.07	7.32	7.4	5.94	6.01	5.60	5.86	5.85
Equivalent, Actual	8.66	8.36	8.99	8.15	9.00	8.34	8.84	8.89	7.13	7.25	6.77	7.00	6.81
Equivalent, Dry Fuel	9.09	8.86	9.52	8.56	9.20	8.56	9.15	9.12	7.54	7.79	7.86	7.58	7.91
Equivalent evaporation per sq. ft, H. S., per hour	9.97	9.94	11.60	11.20	6.96	8.02	9.49	9.97	9.42	6.56	6.8	6.78	6.76
Boiler horsepower developed	792	780	912	873	522	599	813	854	809	469	485	604	604
Boiler efficiency	69.5	66.5	....	....	66.8	58.7	65.5	75.8	60.2	59.6	62.4	64.8	64.2

Kansas briquets show 25% increased evaporation and boiler efficiency over lump coal. The causes to which may be attributed the variation in results of the various fuels tested are discussed further on.

Altoona Laboratory Tests.

In a testing plant, such as is maintained by the Pennsylvania Railroad at Altoona, careful regulation and accurate comparative data are obtainable under varying conditions of engine and boiler performance. This data is valuable in affording results which may be at least approximated under the best road conditions in practice. The fact that they compare favorably with the road tests is encouraging. The briquets used were manufactured at the St. Louis plant from a low volatile high grade friable coal in the form of mine run, mined in Cambria county, Pennsylvania. About equal proportions of square and round briquets were made with 5, 6, 7 and 8% water gas pitch binder. The same coal in mine run form was shipped to the Altoona plant for comparative tests. As this coal is used by the Pennsylvania Railroad, its characteristics as a locomotive fuel were well known. The principal objection to its use was the large percentage of fuel lost through the stack as fine coke, which amounted to as much as 23% when operating under heavy load. To this may be added the front end cinder, which greatly obstructed the draft. The coal produces less smoke than other coals used on the system and this feature made it a valuable fuel for fast passenger and terminal service. The object of these tests was to determine what effect briquetting would have on these characteristics, and in addition, on boiler efficiency and capacity. Tests were made at 4 or 5 rates of combustion for each kind of briquet and the mine run coal, starting with 30 pounds of coal per square foot of grate surface per hour and running to the maximum capacity of the boiler. The maximum rate with coal was 102 pounds, against 127 pounds for briquets, an increase of 25%.

The comparison of coal and briquets at equal rates of combustion, shows an average increase in boiler efficiency of about 15% and an increased equivalent evaporation of 20% in favor of briquets for the different rates compared:

Evaporation per sq. ft. of Heating Surface per hour.	Equivalent Evaporation per pound of fuel Raw Coal.	Briquets.
8 pounds	9.5 pounds	10.7 pounds
10 "	8.8 "	10.2 "
12 "	8.0 "	9.7 "
14 "	7.3 "	9.2 "
16 "	6.6 "	8.7 "

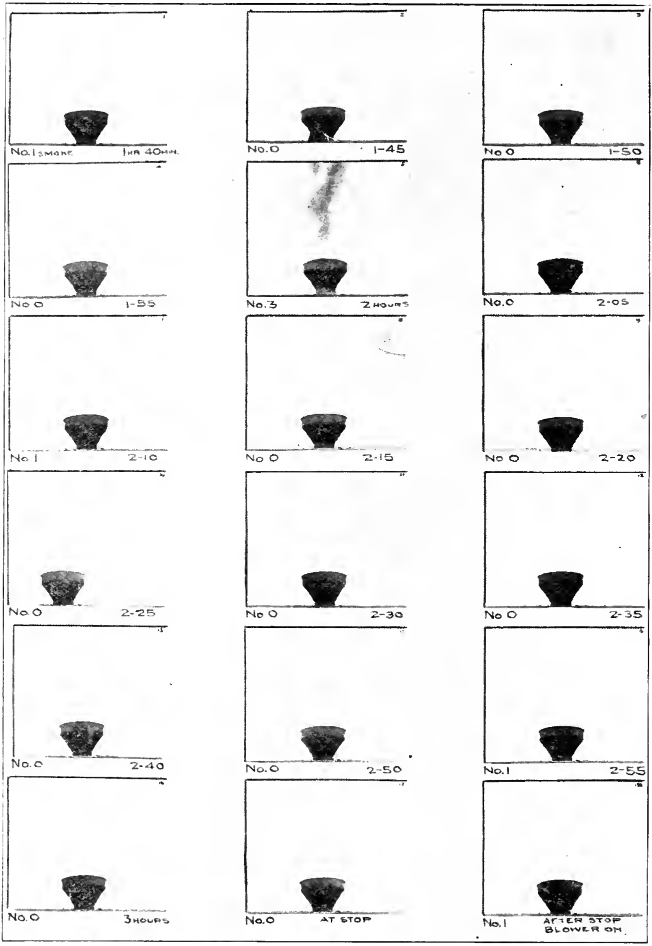

Fig. 18. Smoke observations taken every 5 minutes during test of briquets at testing laboratory of Pennsylvania R. R. at Altoona.

In comparing the coal consumed per dynamometer horsepower per hour, with the total power developed, the record showed a difference of nearly 35% in favor of the briquets, when the engine was working most efficiently. This figure compares favorably with data obtained from road tests on the coal consumption per ton mile.

Smoke readings were taken at stated periods during each test and the density stated in terms of Ringlemann's charts. Based on 5 as representing very black smoke, the average of all readings for coal was 1.5, for round briquets 0.9 and for square briquets 0.6, or in other words the coal made twice as much smoke as the briquets. Fig. 18 shows a series of photographs of the stack at Altoona, taken every 5 minutes during the test. The average smoke record for this test was 0.3.

Importance of Physical Characteristics of Fuel.

When a sample of coal is burned in a calorimeter, all of the combustible is consumed and the total heat value of the fuel is given in British Thermal Units. In practice this result can only be approximated, since there will always be a loss in the stack gases, by radiation and in the fuel left unburned in the refuse. The efficiency of the furnace as a heat producer and of the boilers as a heat absorber play an important part. The real value to the consumer is the evaporation possible in actual practice. The purchase of coal on a B. T. U. basis is an improvement over the old method that "coal was coal" and the lowest price made the cheapest fuel. The physical character of the coal as delivered on the locomotive tank and its behavior in the fire during all conditions met with on the road is often of more importance than its theoretical heat value. An official of the Pennsylvania Railroad once told the writer that his company could afford to pay the same price for a certain coal of higher ash content and consequent lower heating value than for a much cleaner and theoretically superior coal, because the poorer coal made an ash which did not clinker and was easily shaken through the grates.

Combustion.

Coal will burn only where there is sufficient air in the presence of an ignition temperature; and the rate of combustion is usually limited by the air supply and the ability to mix it with the gases from the coal. When a lump of coal burns, the tendency is for the gases to pass off through the lines of least resistance, that is, from the crevices made in the coal as it breaks up in the fire. In the case of briquets there is no

tendency to do this, owing to their homogeneous and porous structure.

If we examine a briquet in the process of burning, as in Fig. 19, we find that it burns entirely from the outside. As the volatile combustible is driven off, a layer of coke is formed which burns to ash and falls off or is carried away by the draft. Thus we find successive layers showing partial combustion of the fuel while the inner part is unaffected, and the briquet retains its identity as such until entirely consumed.

The density of the briquet is of prime importance. Harder briquets do not break up so easily and they burn more slowly

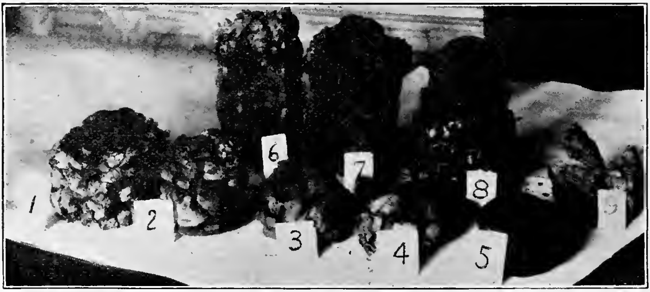

Fig. 19. Briquets made from Hartshorne, Okla., coal showing various stages of combustion. The smaller briquets were made on Renfrow press and weigh 8 oz. each. The larger briquets were made on Johnson press and weigh 4 lbs. each. No. 8 shows the interior of the briquet intact, and outside layer of coke. The depth of the coking is shown in No. 7. In No. 9 the briquet has been reduced nearly to ash. The briquets swell slightly in burning and their efficiency is largely due to the uniformity with which the gases are delivered from the surface of the briquet, and mix with the air.

in the fire. By this means the volatile combustible is driven off more nearly at the rate at which it can be burned with greatest economy, and the briquets form coke during the process of combustion even though made with an otherwise non-coking coal. This is more essential with high volatile than with high carbon coals.

With the harder volatile coals of Illinois, the tendency of the lump coal to break up in the fire is less than with the more friable low volatile coals of the Appalachian field. The eastern coals also produce much more slack in handling so that the main objection to their use as a railroad fuel is the percentage lost through the stack and the coking of the coal in a mass in the firebox. The Arkansas and Oklahoma coals have similar

characteristics. With well made briquets from these good coking coals, the briquets coke separately and do not run together in the fire. It was thought necessary to break the Arkansas four-pound briquets before firing, but the same briquets made from Hartshorne and Loydell coals were fired whole and burned with good results. The eight-ounce briquets did not give as loose a fire and could not be fired with such a heavy bed when made from Illinois coal. It must be observed in this connection, however, that the more friable coals can be made into better briquets with less pressure than the other coals tested.

The whole value of the briquet is due to its uniform size and freedom from slack in handling. These statements are borne out in the tests of Illinois and Missouri coals, where the lump coal did not break up badly in handling, while the briquets used on these tests produced at least 15% slack, which was naturally very fine; a considerable portion being lost through the stack. The fuel could not be "wet down" as uniform conditions had to be maintained for test purposes. These coals do not readily coke so that while a poorly made briquet would hold together, if made from the eastern coal, it would tend to disintegrate when made from these coals. It was therefore necessary to fire with a thin bed as the fine coal would cause heavy clink to form and cut off this draft when a thick fire was carried. It was the usual experience that the briquets made no objectionable clinker and the ash was finely divided and easily shaken through the grates. This is to be expected from the manner in which the coal is prepared before briquetting, and from the uniform distribution of the slag producing elements of the ash, such as iron pyrites, throughout the briquet.

Smoke and Cinders.

The reduction in cinders and sparks by briquetting depends on the quality of the coal as well as the density of the briquets. Certain coals, like the Loydell coal, produce a fine scale of coke in burning which is often loosened from the surface of the briquet by the action of the draft and carried partially burnt through the stack. With Hartshorne and Arkansas coals the coking is much different in character, probably due to the higher ash content, and these coke scales are scarcely noticeable. The same difference was noticed in burning briquets made from Pocahontas coal and "bone coal" picked from the mine run coal. The latter was high in ash and the scales were greatly reduced.

The results at Altoona show no appreciable reduction in

Fig. 20. Burning briquets made from Pocahontas coal on tugboat running under full speed in harbor at Norfolk. Photograph taken at time of firing.

Fig. 21. Another view of tug shown in Fig. 20 burning Pocahontas coal, under similar conditions. Photographs were taken every 15 seconds for five minutes to cover a "firing period," and these photographs illustrate the densest smoke observed.

the weight of cinders from briquets, but a decided reduction in their calorific value.

During December, 1907, a test of briquets was made on the U. S. S. Connecticut between New York and Hampton Roads. The results were so encouraging that more briquets were ordered by the Navy Department for test during the trip of the fleet around the world. Figs. 22 and 23 are from photographs taken by the writer as the ships passed out the Capes and illustrate the relative smoke producing qualities of raw and briquetted coal. Various samples of Pocahontas and New River coals were briquetted and tested for burning qualities on tug boats in Hampton Roads. The boilers were fired at intervals of five minutes, known as "firing periods," and as nearly as possible the same furnace conditions and service were maintained throughout the test. Photographs were taken every fifteen seconds covering a firing period and one series taken an hour while smoke readings were taken every fifteen seconds throughout the test. Figs. 20 and 21 illustrate the densest smoke observed for similar tests of briquetted and raw coal.

Firing.

The work of the fireman is reduced by the use of briquets. Their uniform size makes the handling easier; it is easier to keep up steam and only necessary to fill up the holes in the fire without leveling. No slicing is necessary as is usual with eastern coals. The comparative absence of clinker, when briquets are properly fired, is a big advantage in forcing the boiler for heavy grades or higher speed.

Summary of Advantages of Briquetted over Raw Coal.

In general the following advantages may be claimed for briquets made from bituminous coal over the same coal not briquetted:

1. Comparative absence of smoke.
2. Uniformity of size and quality.
3. Less loss of fuel in ash.
4. Increased furnace and boiler efficiency.
5. Reduced consumption of fuel per ton mile.
6. More fuel can be burned per square foot of heating surface, hence greater capacity.
7. Less slack in handling fuel.
8. Less clinker and cinders.
9. Longer life of grates.
10. Fires can be kept up for longer period without cleaning.

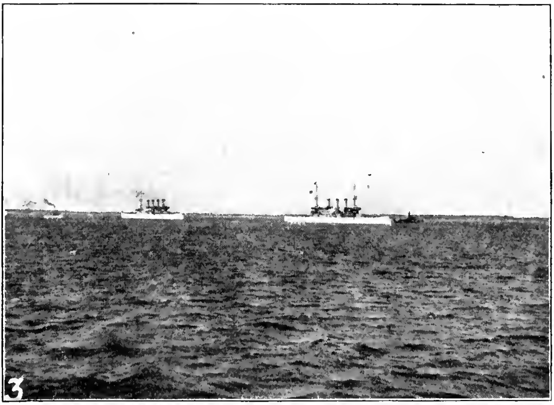

Fig. 22. Fleet passing out the Capes, December 16, 1907. U. S. S. Connecticut burning briquets.

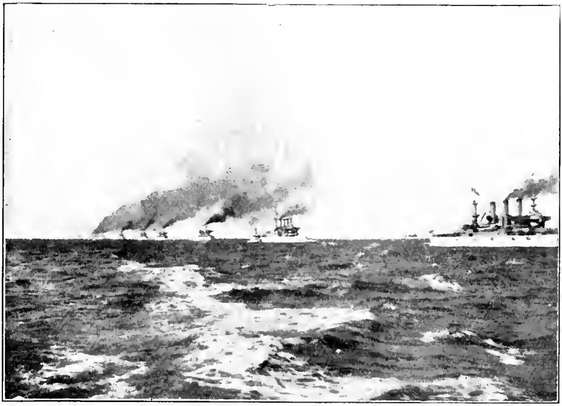

Fig. 23. Remainder of fleet burning coal. All of the ships were well under way and boilers working under similar conditions.

11. Less cleaning of tubes.
12. Less labor in firing, hence
13. Greater efficiency of fireman.
14. Less draft needed.
15. More uniform steam pressure.
16. Steam pressure can be increased more rapidly.
17. No liability to spontaneous combustion.
18. Availability for storage without deterioration.

CATALYSIS, OR CONTACT ACTION.†

BY B. B. FREUD.*

Hydrogen and oxygen can exist side by side in the same containing vessel without any perceptible combination or reaction taking place. Introducing a bit of platinum, in the proper state of division, into such a mixture, however, causes an immediate reaction, an explosively violent one. Such a reaction is a catalytic one. The platinum is termed the catalyzer.

On considering the illustration just given, it is seen that thus increasing the speed of a chemical action requires, apparently, the expenditure of no energy whatever. The employment of the platinum adds nothing to the energy the hydrogen and oxygen originally possessed. The platinum itself is recovered, without being in any way altered, in its entirety and is just as efficient after the action as before. Theoretically, the use of the platinum costs nothing. The increased speed in the reaction of the hydrogen and the oxygen is obtained without cost. In this connection Ostwald says, "When we consider that the acceleration of a reaction by catalysis is achieved without consumption of energy, and so proceeds in this sense gratis, and that in chemical industry as in all other, time is money, we perceive that the systematic utilization of catalytic appliances is likely to lead to the most thorough going changes in manufacturing processes."

The phenomenon of catalysis was first recognized as such by Berzelius in 1835. The role of the sulphuric acid in the formation of ether from alcohol, the action of dilute acids and of malt extract on starch, the decomposition of hydrogen peroxide under the influence of metals and oxides, the action of finely divided platinum in mixtures of certain gases, all led him to the conclusion "that substances **by their mere presence** and not by their affinity have the power to rouse latent affinities so that compound substances undergo reaction and a greater electrochemical neutralization occurs." And this conclusion, after

†In the preparation of this report, free use has been made of Smith's General Inorganic Chemistry; the chapter on Catalysis in Duncan's Chemistry of Commerce; Ostwald's article on Catalysis in Nature, Vol. 65; Stieglitz' article in the Congress of Arts and Science, St. Louis, 1904, Vol. IV, and Stieglitz' various articles in the American Chemical Journal, 1908, et seq. To all of these due acknowledgment is made.

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making allowances for the development of the science since 1835, is correct in the light of present knowledge.

It must not be supposed that catalytic reactions and catalytic substances are uncommon. Quite the contrary is the case. In fact there seems to be no kind of chemical reaction which cannot be catalytically influenced and no chemical substances, whether elements or compounds, which cannot act catalytically. It must not be supposed, however, that a catalyst can be found to inaugurate any possible chemical change. No reactions are possible under the influence of catalysts that could not take place in their absence without a breach of one of the laws of energy. The original change may proceed, no doubt, very slowly, as in the action of hydrogen and oxygen mentioned in the first paragraph of this paper. So slowly may this change proceed, that without careful quantitative measurement specially directed to the point no change at all can be observed. The laws of energy demand that the reaction must take place without the presence of the catalyser. They prescribe no numerical value to the velocity of the change, they prescribe only that it shall not be zero, that it shall have some finite value, however small.

Since, then, any chemical action that can take place at all can be catalytically influenced, this influence must have vast consequence in technical application. And before taking up further our inquiry into the nature and cause of catalysis, I will mention some of the technical applications of the phenomenon. All of the ferments and enzymes are catalysts. Hence all of the fermentation industries are catalytic in their nature. Chlorine is made by the Deacon process, in which hydrochloric acid is oxidized by air in the presence of copper chloride, the resulting chlorine being used in various substances of commerce. Not only is this particular application of catalysis valuable in itself, but the utilization of the hydrochloric acid, a by-product of the Le Blanc soda process, makes it the more valuable because thereby it saves the entire Le Blanc process from commercial annihilation. Another catalytic application in the soda industry is the Claus-Chance process, by which the "tank waste" is used as a source of hydrogen sulphide, which, when mixed with air is passed over iron oxide and changed into water and the commercially valuable sulphur. The manufacture of 'salt-cake" by the Hargreaves-Robinson process is also a catalytic application. Here sulphur dioxide and air react with common salt in the presence of copper chloride and the valuable "salt-cake" and chlorine are produced. The greatest of all applications of catalysis is the manufacture of sulphuric acid by the "contact" process. Of course the original "chamber"

process is also a catalytic one, but the newer "contact" process has more of the characteristics of a catalytic action apparent in it. This process stands as one of the greatest achievements of industrial application of the catalytic idea. Another great triumph of technical chemistry, the synthesis of indigo, is also based on a catalytic action, the oxidation of naphthalene by sulphuric acid in the presence of mercury. It may be mentioned that this successful preparation of indigo on a commercial scale has resulted in an agricultural revolution in India. Then there is the oxidation of ammonia to nitric acid under the influence of platinum black, and the oxidation of methyl alcohol to formaldehyde and "formalin" under the influence of the same agent. Platinum is also the catalyst in one of the reactions in the synthesis of vanillin, "artificial vanilla." Copper compounds are used as catalysts in the manufacture of various dyes, such as aniline black and methyl violet. Manganese and lead compounds used as "dryers" in the oxidation of linseed oil, act catalytically. Iodine, in the manufacture of that universal organic solvent, carbon tetrachloride; barium carbonate, in the manufacture of acetone from acetic acid; nickel, in the manufacture of stearic from oleic acid; lime, in the metallurgy of lead; zinc, in the manufacture of aldehyde from alcohol; these all are technical applications of the phenomenon of catalysis.

Thus we see **what** a catalyst can do. **How** it accomplishes these remarkable results, the mechanism of its action, this has been the inspiration of many hypothetical assumptions, which did little service other than to delay experimental work and so postpone a scientific explanation of the phenomenon. In recent years much experimental evidence, particularly of a quantitative nature, has been obtained. This of course is vital to a scientific explanation of the nature and mechanism of the phenomenon. And since we have seen that the applications of catalysis in the industries are so important and so extensive, whatever will be discovered in regard to the nature of catalysis will find immediate applications in the industries. Hence, I may say with Ostwald that the subject has not only a chemical interest, but that the scientific knowledge and investigation of catalysis must have vast consequences in technical application.

To recall the specific problem to our minds, let us examine the example given in the first paragraph. It will be remembered that the hydrogen and the oxygen both remained peacefully inactive in each others' presence so far as we could see. On introducing the platinum, however, the two gases immediately and explosively reacted. It is evident that the addition of the catalyzer cannot add to the intrinsic energy contained in

the original substances, and therefore, it cannot increase their intrinsic energies to unite. It increases the speed of the reaction merely. The platinum itself is recovered unchanged, and as efficient as ever. How this increase in speed is effected, that is the problem. Of course the "increase in speed" is to be taken in a negative as well as in a positive sense. For while by far the greater percentage of catalytic reactions show a tremendously increased velocity, nevertheless a few reactions are on record which are catalytically retarded.

It may be that there is no **general** answer to the question, why and how catalyzers exert their marvelous accelerating influences. Such a generalization would be possible only after a study of a large number of individual cases. One of the most important contributions to the subject has been made by Stieglitz and his co-workers, whose experimental evidence shows exactly how the particular catalyzers in the particular reactions they studied, accomplish their results. And there is no doubt but that the conclusions of Stieglitz in this study can be very largely generalized. In the endeavor to answer the question as to how and why a catalyzer works, he studied the catalysis of methyl acetate under the influence of water and acids. The following are the facts. The saponification of methyl acetate by water proceeds very slowly, according to the following equation:

$$CH_3COOCH_3 + H_2O \rightarrow CH_3COOH + CH_3OH. \quad (1)$$

Acids greatly accelerate the saponification proportionately to the concentration of the hydrogen ion used. It has been shown, also, that the final condition of equilibrium of the reversible reaction,

$$CH_3COOH + CH_3OH \rightarrow CH_3COOCH_3 + H_2O, \quad (2)$$

is not appreciably altered by the catalyzer. In other words, that the acid accelerates the velocity in either direction to the same extent. It has also been shown that the catalyzer, the acid or hydrogen ion, appears to act by its presence, simply; that it appears to remain unchanged throughout the course of the reaction. These three properties have been assumed to be typical of all catalytic actions.

Stieglitz took the first vital and decisive step when he departed from the old idea that catalytic action may be studied only in reactions which complied with these three fundamental principles, which for emphasis I will repeat; first, that the ac-

celeration is proportional to the concentration of the catalytic agent; second, that the condition of equilibrium in a reversible reaction must not be measurably changed by the presence of the catalytic agent; and third, that the catalytic agent must appear to act by its presence simply, and not to form a compound in quantity with any other components. These three properties have, in the past, been assumed to be necessary and typical of catalytic action, but, in this study, the vital fact of **acceleration** (in a positive or negative sense), alone was considered characteristic.

In regard to the acceleration of the velocity of saponification of methyl acetate (equation No. 1) by acids, the most fundamental fact concerning acids, namely, their ability to form salts with bases and oxides, suggested itself. The logical conclusion was that the methyl acetate has basic properties, and the salt formation with acids is intimately connected with, if not the cause of, the catalysis. Of course, the basic properties of methyl acetate must be far too weak to permit of quantitative measurement of its constants, so the class of closely related bodies, the imido esters, whose quantitative measurement of all necessary factors could be had, were studied. The imido esters are esters in which the imide group (=N—H) replaces the oxygen atom of the ester, as in imido methyl acetate $CH_3C(=NH)OCH_3$. These are distinctly basic substances which form well defined salts. The free bases are very slowly decomposed by water, chiefly according to

$$C_6H_5C\,(=NH)\,OCH_3+H_2O \rightarrow C_6H_5CONH_2+CH_3OH \quad (3)$$

and yet more slowly according to

$$C_6H_5C\,(=NH)\,OCH_3+H_2O \rightarrow C_6H_5COOCH_3+NH_3, \quad (4)$$

both reactions being practically non-reversible. The addition of hydrochloric acid greatly increases the velocity of the second reaction (equation No. 4), which becomes almost the exclusive one. How does the acid accelerate the reaction? That is the question. The acid forms the hydrochloride, but as the imido esters are weak bases, partial hydrolysis takes place and a condition of equilibrium results, thus

$$C_6H_5C\,(NH_2Cl)\,OCH_3 + H_2O \rightarrow C_6H_5C\,(NH_2OH)\,OCH_3 + HCl \quad (5)$$

The reaction presents, therefore, at least three possibilities, the velocity may be proportionate to the concentration at any

moment of the salt, to that of the free base, or to the total substance,

$$\frac{dx}{dt} = K_{salt} \cdot (\text{salt}), \tag{6}$$

$$\frac{dx}{dt} = K_{base} \cdot (\text{base}), \tag{7}$$

$$\frac{dx}{dt} = K_{substance} \cdot (\text{substance}). \tag{8}$$

In order to decide between these three, it was necessary to determine experimentally the actual change (X) in time (t), and also the proportions of salt, free base, and acid present at any moment (t). This latter is determined according to Arrhenius' equation for the solution of a hydrolyzed salt

$$\frac{\text{Positive ion}}{\text{base} \cdot \text{H}} = \frac{K_{base}}{K_{water}} = K_{hydrolysis}, \tag{9}$$

The constant K was determined by conductivity measurements, and with its aid the concentrations of salt, base, and acid for the differential equations (6, 7, and 8) were calculated. The results show that the true course of the reaction is given by equation (6), which alone leads to a true constant. It is therefore certain that hydrochloric acid which enormously increases the velocity of saponification of the imido ester according to equation (4), does so **simply and quantitatively on account of salt formation.**

The accelerating or catalytic action of the acid is here surely due then to salt or ion formation of a different, less stable, more reactive molecule.

This increase in the velocity of a chemical action is the main characteristic of the phenomenon of catalysis, and we have seen a simple explanation of it based on rigorous experimental proof. Now it remained to ascertain whether the two other important characteristics for many catalytic reactions, namely; the fact that the catalyzing agent need not appear to combine with any of the reacting substances, and the fact that

in a reversible reaction it need not measurably change the final condition of equilibrium, are also in agreement with this conception of the course of a catalytic reaction.

The following experimental evidence shows why the catalyzing acid need not appear to combine with any of the reacting substances. It was shown that the saponification of imido esters takes place according to

$$\frac{dx}{dt} = K_{salt} \cdot (\text{salt}), \tag{6}$$

According to Arrhenius and Walker

$$(\text{salt}) = K \cdot (\text{base}) \cdot (H), \tag{10}$$

substituting,

$$\frac{dx}{dt} = K' \cdot (\text{base}) \cdot (H). \tag{11}$$

Now this is exactly the velocity for ester catalysis, substituting "(ester)" for "(base)." This shows the connection between the catalysis of the imido esters and that of the ordinary esters. For if the latter could be considered to be a base, and could form salts, its saponification could undoubtedly be due to the saponification only of its salt or positive ion. This link in the proof was supplied by Baeyer, who showed that esters form well defined salts (oxonium or quadrivalent oxygen salts) with acids, very unstable ones, but nevertheless salts: and Coehn proved that they are electrolytes. According to this idea we can write for the reaction,

$$CH_3COOCH_3 + H_2O \rightarrow CH_3COOH + CH_3OH \tag{1}$$

the following:

$$\frac{dx}{dt} = K_{saponification} \cdot (\text{positive ester ion}) \cdot H_2O \tag{12}$$

as was proved experimentally for the imido esters.

For the combination of methyl acetate with water to form an oxonium base and for its ionization, we have,

$$CH_3COOCH_3 + H_2O \rightleftarrows CH_3CO\underset{\underset{H}{\cdot}}{\overset{\overset{OH}{\cdot}}{O}}CH_3 \rightleftarrows \overset{+}{\overline{CH_3CO\underset{\underset{H}{\cdot}}{O}CH_3}} + \overset{-}{\overline{OH}}, \quad (13)$$

consequently,

$$(\text{Positive ester ion}) = \frac{K_{base}}{K'} \cdot (\text{ester}) \cdot (H) \qquad (14)$$

Substituting in equation (12) we have for the saponification of methyl acetate by water,

$$\text{Velocity of saponification} =$$

$$K_{sap} \cdot \frac{K_{base}}{K'} \cdot (\text{ester}) \cdot (H) \cdot (H_2O). \quad (15)$$

If we saponify with hydrochloric acid the reaction similarly will be,

$$CH_3COOCH_3 + HCl \rightleftarrows$$

$$CH_3CO\underset{\underset{H}{\cdot}}{\overset{\overset{Cl}{\cdot}}{O}}CH_3 + H_2O \rightleftarrows CH_3CO\underset{\underset{H}{\cdot}}{\overset{\overset{OH}{\cdot}}{O}}CH_3 + HCl \quad (16)$$

According to Arrhenius, the equation for hydrolyzed solutions of salts of weak bases with strong acids, is

$$\text{Positive ester ion} = \frac{K_{base}}{K'} \cdot (\text{ester} - y) \cdot (H'). \quad (17)$$

For an almost completely hydrolyzed salt "y" is negligible.

Hence the velocity of saponification of methyl acetate in the presence of hydrochloric acid becomes

$$V_{sap\,\cdot\,HCl} = K_{sap} \cdot \frac{K_{base}}{K'} \cdot (\text{ester}) \cdot (H') \cdot (H_2O) \quad (18)$$

Comparing the two velocity equations (18 and 15) for the saponification in the presence of water alone, and in the presence of acid, it is seen that the velocity must in fact increase directly proportionate to the concentration of the hydrogen ion, since all other factors remain constant. Hence the experimental results do not dispute the consequences of the theory.

And now, the last important fact, namely, that in a reversible reaction, the catalyzer need not measurably change the final condition of equilibrium. The saponification of methyl-acetate is a reversible reaction.

$$CH_3COOH + CH_3OH \rightarrow CH_3COOCH_3 + H_2O \quad (19)$$

The velocity of this reaction is also accelerated by the addition of hydrochloric acid. This increased velocity under the influence of an acid must be due to minimal basic properties of acetic acid, or methyl alcohol. Surprising as it may seem, it is to the basic properties of acetic acid that we must look in this instance. Other workers, Rosenheim and Euler, have shown that acetic acid must form oxonium salts and have some basic functions. Applying this conception to the study of the velocity of esterification, the velocity in the absence of water is,

$$V_{esterification} = K_{est} \cdot (\text{pos. acetate ion}) \cdot (CH_3OH), \quad (20)$$

$$= K_{est} \cdot \frac{K'_{base}}{K''} \cdot (\text{acetic acid}) \cdot (H) \cdot (CH_3OH). \quad (21)$$

In the presence of acid, the equation becomes,

$$V_{est\,\cdot\,HCl} = K_{est} \cdot \frac{K'_{base}}{K''} \cdot (\text{acetic acid}) \cdot (H') \cdot (CH_3OH). (22)$$

The change in the velocity of esterification is seen to be proportionate to the change in concentration of the hydrogen ion. This is in accord with the theory proposed, and is with

the experimental parts. When equilibrium is established, in absence of acid,

$$V_{\text{saponification}} = V_{\text{esterification}}, \text{ or} \tag{23}$$

$$K_{sap} \cdot \frac{K_{base}}{K'} \cdot (\text{ester}) \cdot (H_2O) \cdot (H) =$$

$$K_{est} \cdot \frac{K'_{base}}{K''} \cdot (\text{acetic acid}) \cdot (CH_3OH) \cdot (H) \tag{24}$$

and in the presence of acid,

$$V_{\text{saponification HCl}} = V_{\text{esterification HCl}}, \text{ or} \tag{25}$$

$$K_{sap} \cdot \frac{K_{base}}{K'} \cdot (\text{ester}) \cdot (H') \cdot (H_2O) =$$

$$K_{est} \cdot \frac{K'_{base}}{K''} \cdot (\text{acetic acid}) \cdot (CH_3OH) \cdot (H') \tag{26}$$

In other words the addition of the catalyzing acid will not effect the ultimate condition of equilibrium between the components of the reaction.

In accordance with these results of Stieglitz, and his co-workers, our views concerning catalytic action must be modified in regard to all three of the commonly assumed fundamental characteristics of catalytic action. These three characteristics are practically true only for limiting cases, where the amount of salt formation is too small to measure. None of them are absolutely true under any condition.

The one vital fact, OF AN ACCELERATION DUE TO AN INCREASE IN THE ACTIVE MASS OR CONCENTRATION OF A REACTING COMPONENT IN A CATALYTIC ACTION is the ONLY fundamental fact common to ALL catalytic action.

GAS CALORIMETRY.

BY C. E. BECK.*

Up to about ten years ago little was known in the United States about gas calorimetry and its commercial possibilities. A number of the technical institutions had gas calorimeters, as did also several of the large gas manufacturing companies, but its use by the latter was not intended to be of any great commercial value. As a matter of fact there was no object in knowing the heating value of a gas, because a candle-power criterion was the acknowledged standard and a gas having the required illuminating qualities usually ran high enough in heat value to cope with all practical requirements. In Germany, however, greater stress had been laid upon the thermal qualities of a gas, it, perhaps, being due to their more advanced commercial means of using gas. It is very evident that Germany is without a peer as regards the development of the internal combustion engine, and from this it is natural to assume that she is not inferior to anyone in gas manufacturing.. Things progressed rather slowly in the United States until the gas engine manifested its commercial possibilities. The gas calorimeter at once fell into demand as gas engine manufacturers were incited to make guarantees based on the heat value of the gas to be used in their engines. It was entirely a matter of heat value that regulated the rating of internal combustion engines, and with a few exceptions gas constituents were not considered.

It is now estimated that about 90% of all the gas manufactured is used for power, heating and incandescent lighting, and it is very evident that these three factors depend entirely upon heat value for their output. With this in view the civic authorities in some of our states enacted laws whereby all gas companies having a certain minimum output of gas per year were compelled to maintain a given standard heat value of their gas. Wisconsin was the first state to enact these measures, being followed by New York and quite a number of other large cities. Consequently, gas calorimetry as well as the gas calorimeter now received quite an impetus, but the question that troubled the minds of authorities was what calorimeter would be the most satisfactory to use. As a result the American Gas Institute appointed a committee on calorimetry to investigate and conduct exhaustive tests on all available instruments.

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*Class of 1911, Armour Institute of Technology. Manager, Sargent Steam Meter Co., Chicago.

Gas calorimetry may be defined as the quantity of heat generated by the complete combustion of a unit volume of gas. The apparatus used to determine this quantity is called a "Calorimeter," which when complete consists of a calorimeter proper, a gas meter, governor, thermometers, weighing buckets

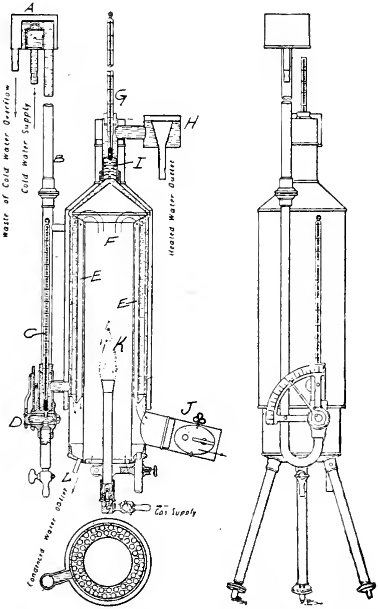

Fig. 1. Junkers Calorimeter. Sectional Views and Elevation.

and scales. In this article only the water heater type of instrument will be dwelt upon, as it has proven to be the most satisfactory. In its performance the heat generated by the complete combustion of a unit quantity of gas is absorbed by a given weight of water, thereby causing a rise in temperature. The unit in which this heat is measured is called a British Thermal Unit in the English system, and is defined as the

quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit at 62° F.

There are but four gas calorimeters manufactured that are worthy of mention, and only two of these have wide application in commercial practice. The first instrument to be described is the Junkers, a sectional and external elevation of which is

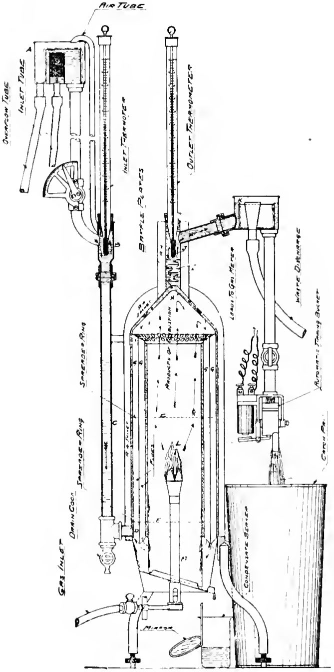

Fig. 2. Sargent Automatic Gas Calorimeter. Sectional Elevation.

shown in Fig. 1. This instrument was designed by Hugo Junkers of Germany, and is perhaps the best known instrument of its kind, although it is being supplanted by the Sargent, an American made instrument, to be described later.

In Fig. 1, water at approximately room temperature enters

the weir "A," flowing down the inlet pipe "B" to the thermometer at "C," where the temperature is taken. A quadrant valve "D" is used to regulate the rate of flow. The water on entering the instrument flows upward against the direction of flow of the products of combustion, which come down through the thin copper tubes "E," being discharged at room temperature

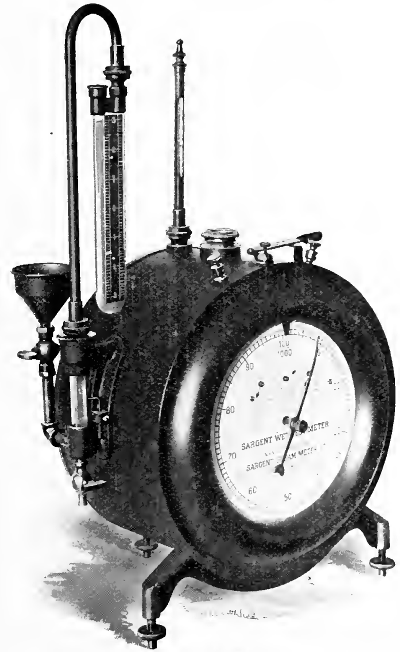

Fig. 3. Gas Meter.

through the flue "J," where a damper regulates the velocity of discharge. Combustion of the gas takes place at "K," a Bunsen burner being used for the purpose. The water passing upward absorbs the sensible heat liberated by the products of combustion as well as the latent heat given up by the conden-

sation formed in the combustion of hydrogen and other hydrocarbons. At "I" a series of baffle plates thoroughly mix the water, which, after passing over the outlet thermometer "G," where the outlet temperature is taken, is discharged through the weir "H." About the only criticism to be offered on this instrument is that the inlet and outlet thermometers not being on the same level make it a tiresome operation for an observer to perform continuous runs.

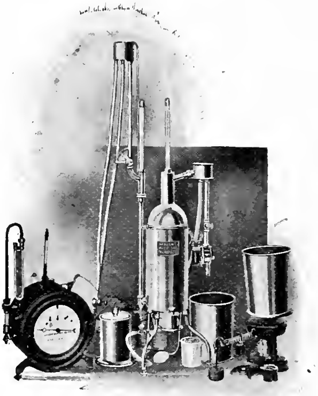

Fig. 4. Complete Apparatus for Gas Calorimetry.

The Sargent Automatic Gas Calorimeter, section elevation of which is shown in Fig. 2, was designed by C. E. Sargent of Chicago, who, through his experience with internal combustion engines, realized the application and value of a gas calorimeter in commercial practice. The Sargent instrument, since its inception, has been built in several different models, each one better than the preceding. In the figure is shown the latest model which is now recognized as a standard and which embodies all the suggestions set forth by the Committee on Gas Calorimetry of the American Gas Institute. In construction the Sargent instrument does not differ widely from the Junkers. The inlet and outlet thermometers are on the same level and the device is equipped with an electrical automatic attach-

ment so that at each revolution of the gas meter needle, the discharge water is automatically switched from one receptacle to another. By this means continuous operations can be performed and the personal error in switching a hose eliminated. The efficiency of the calorimeter is about 99.5%. As a complete outfit the Sargent apparatus is recommended be-

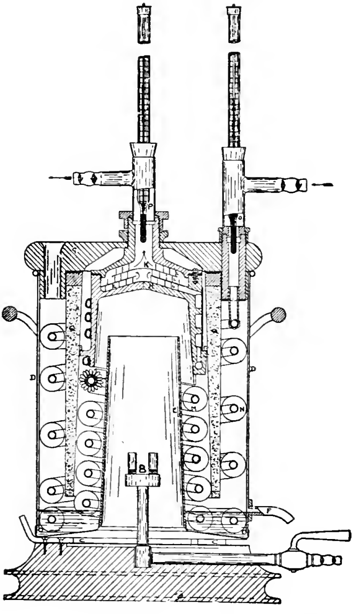

Fig. 5. Boys Calorimeter. Sectional View.

cause the heat value of a gas is computed in English units direct, by the use of Fahrenheit thermometers and decimal scales which weigh the discharge water to .01 of a pound. The gas meter measures 1/10 of a cubic foot per revolution and with its integrating train has a range of from .001 to 100 cubic feet. The meter is equipped with a single "which-way" level, has three leveling screws, a drain, filler, thermometer and a U-gauge. The entire outfit is made of brass and copper. Fig. 3 is a cut of the meter and Fig. 4 the complete apparatus.

The Boys Calorimeter, shown in Fig. 5, was designed by C. V. Boys of London, England, and has been adopted by the London Referees for determining the heat value of London gas. This instrument is not very satisfactory on account of the whole body having to be removed to light the burner "B." It also has a burner that produces a luminous flame, and when burning a gas containing a considerable quantity of hydro-

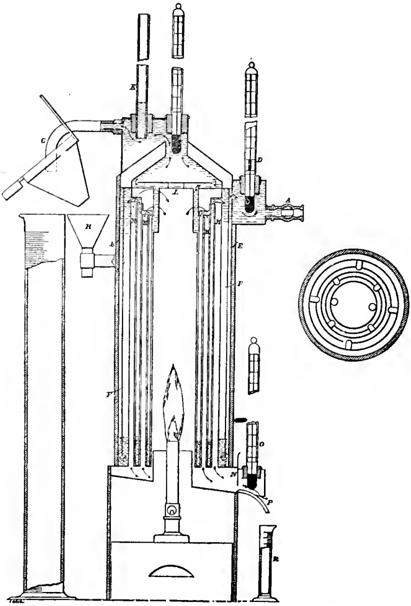

Fig. 6. Simmance-Abady Calorimeter. Sectional View.

carbon, a carbon deposit is effected, indicating incomplete combustion. It will be noted that the products of combustion pass up a central flue and then down and up over a coil provided with considerable heating surface, and through which the water passes.

The Simmance-Abady Calorimeter, shown in Fig. 6, is another English instrument, and differs in construction from any yet shown. The water and products of combustion pass

up and down through a series of annular chambers. The device is lagged with wood, which has been found inferior to a metal jacket, and the outlet thermometer comes in direct contact with irregularly heated water, which is not churned by baffle plates and which causes wide variations in the outlet temperatures. The annular chambers and their connections cause air trapping, and at times a very irregular flow of water. The excessive weight of the Simmance-Abady also renders it impossible to detect slight changes in the heat value of a gas on account of the heat inertia set up by the excess metal.

As a standard the Boys and the Simmance-Abady instruments are not considered in the United States. The Sargent and the Junkers are recommended, there being about 150 of the former now in use, with the demand rapidly increasing.

Of course, there are many things about gas calorimetry and the design of a gas calorimeter that have not been mentioned in this article. Take for instance the effect of using water below and above room temperature, the effect of humidity, rate of combustion and of varying the temperature of the discharge products of combustion. All of these factors are responsible for the errors manifested in commercial results, but as their combined effect under the most unfavorable conditions does not cause excessive errors, corrections are usually neglected. In calorimeter design it is advisable to use light material in order to reduce the effect of heat inertia to a minimum. The water of contents should be as small as possible in order to detect slight changes in heat value quickly and accurately. The inlet and outlet thermometer, should have no heat communication with each other, the outlet water must be thoroughly mixed and a uniform flow should be maintained by the use of weirs. By all means a metal surrounded air jacket is always advisable as the evaporation of water spilled on a wood jacket will lower the heat value of the gas being tested.

The above suggestions as well as many others of minor consideration have been incorporated in the Sargent and Junkers instruments, and when we consider convenience of operation, accuracy and efficiency, these instruments have no equal.

ARTESIAN WATER IN THE ORIENT.

BY TENNEY S. FORD.*

The water supply for old Sidon, a town of some 10,000 people built on or very near the ruins of the ancient Phoenician city of the same name, is piped about two miles from a river flowing by the city on the north. The built-up portion rises gently back from the sea to perhaps seventy-five feet above sea level, and is crowned by an old Crusader castle, which overlooks the city and the surrounding fields and gardens. Distribution of water is made in the lower town from a standpipe which will send water to an elevation of about sixty-five feet; so that the upper town is not furnished with running water. Rising up thru the center of the stone tower is the main pipe, which overflows inside of an open stone basin some four feet in diameter. Holes in the rim of this basin, of equal size and under equal head, gauge the units of supply, and these units are sold outright at the tower for a market price, just as land would be. From here an owner may do as he pleases with his supply—pipe it to any place as a whole or in part, or sell any part of it.

Such a system of course involves the use of many long strings of small pipe and this causes the principal drawback to its use, for in the rainy season much fine silt goes the full length of the system, finally to settle in the small pipes and eventually to close them. Partly to avoid this, the water is cut off toward the end of the dry season for a week or so, while the mains are cleaned, and at such times the people have to use the brackish water of old wells under the houses or else pack spring water in jars from some distance. Of course, the fact that the river water is largely surface drainage adds to the danger of pollution, but modern orientals seem to have paid less attention to that, until very recently, than even the ancients did.

Under these conditions the Americans in charge of the Mission Schools sank two drilled wells to about 900 feet, and the water in them rose from about 750 feet below sea level to 20 feet below the surface of the school yard, which is there at an elevation of +50 feet. This was in 1901, and for some years a rather unique pumping system was in use. The first 45 feet was drilled thru the earth filling of the old city moat over which the school stands, and this had been dug out around the casing down to an elevation of +5.0 feet, where a coarse

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*Class of 1906, Civil Engineer, Board of Local Improvements, City of Chicago.

brown sandstone that underlies the whole region was found. It was noticed that considerable amounts of water, which overflowed the casing during drilling, escaped quite freely thru this sandstone. Using this fact, the idea was hit upon of joining the two wells (about 90 feet apart) with the drive pipes of two hydraulic rams, these pipes taking the water from one well and delivering it to the rams set on a platform in the other well, this well receiving the overflow from the waste valves.

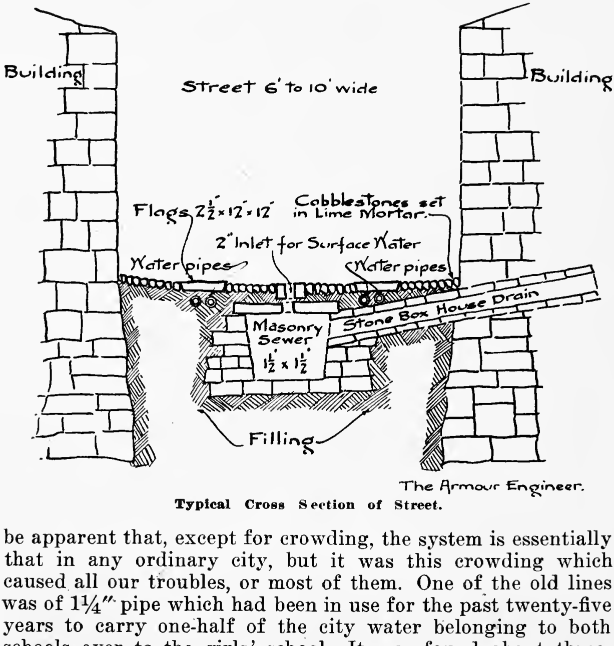
For a long while the porous sandstone carried off this waste, but finally dust and dirt sifted in to such an extent as to clog the pores so that the larger ram, and then the smaller one, had to be stopped. This was no small hardship to both the school and the neighbors, for many had made good use of the little stream kept flowing outside the school compound in a sort of public fountain. Hand pumps were put in, but their use by townspeople during school hours was a great annoyance, and the forcing of water from the boys' school, where the wells were, thru the town some thousand or eleven hundred feet to the girls' school, to supply about one hundred people, was a tiresome job.

During a year spent in 1909-1910 assisting in various projects connected with the schools and the Industrial Farm belonging to them, the writer helped to remedy the conditions outlined above. An underground pump room was dug out around the well, walled up, and arched over so as to leave the boys' yard undisturbed except for an entrance way. In this was installed a ten-inch Rider-Ericsson hot air engine, chosen because of its simple build and action as perhaps the best adapted to such a distance from repair facilities, and to operation by a native workman. A system of distribution pipes and tanks among the various school buildings was arranged, not without some difficulty owing to the native architecture, for

Sidon as Viewed from Seminary Compound.

when those innumerable corners had to be turned and the heavy walls pierced for such modern innovations as bath-room plumbing, it was no easy matter. However, the real experience of the job, amusing enough in the narration, but far from amusing at the time, was the tearing up of the old piping between the two schools and the laying of new and larger pipe, by another route.

In the accompanying sketch of a typical cross section of a Sidon street can be seen the general arrangement of paving, drains and sewers, and water pipes when there are any. It may



Typical Cross Section of Street.

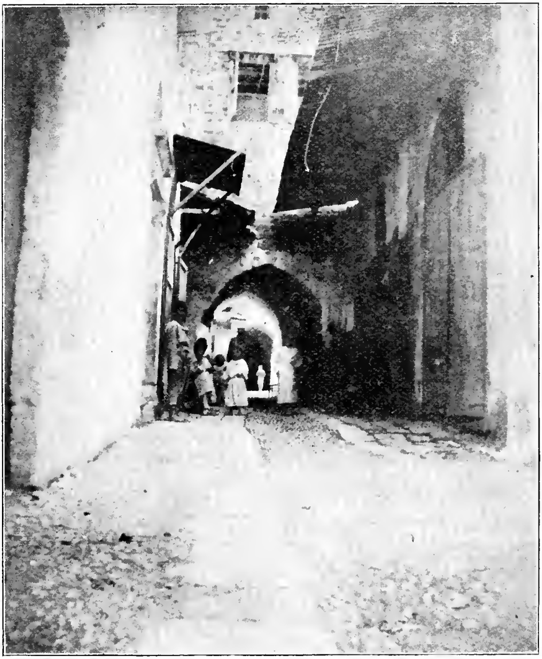
be apparent that, except for crowding, the system is essentially that in any ordinary city, but it was this crowding which caused all our troubles, or most of them. One of the old lines was of 1¼" pipe which had been in use for the past twenty-five years to carry one-half of the city water belonging to both schools over to the girls' school. It was found about three-fourths full of fine river silt, but, considering its age, not badly corroded. The other, a 1-inch pipe used with the pump and ram for artesian water, was so badly eaten on the inside after only eight or nine years, that a man's little finger would scarcely en-

ter the end. In the recent purchase of some property, the Mission acquired another unit of city water for use at the girls' school, and this was fed from a sort of sub-station along the line of our work, to which we made connections. These smaller standpipes are scattered all over the town and are fed from the main tower in larger pipes than individuals would use, thus saving expense and friction, both of which facts even the oriental has found out.

For the supply of artesian water to the other school we used a lot of 3-inch pipe, already on hand, and this we connected to the discharge main from the air engine. Right here our troubles began. Often we came to some old house drain almost falling to pieces and built so high that between the cover flags of the drain and the paving flags there was no room for the pipe; then if the drain fell apart, it had to be rebuilt. At some other time a slight bend would occur in a narrow part of the street, too small to use any angle fitting we could possibly procure, and since our pipe supply was limited, and even standard fittings were scarce articles, we were forced to bend our pipes. A pipe sixteen feet long, by the way, with a bend near the fixed end, was not the easiest thing in the world to connect in cramped quarters. Add to this the fact that the paver was replacing the flags only two or three joints back, so as to keep as little of the street open as possible, and that every lifting of the end of the pipe jarred his work and scraped off the tar that had been used to protect the pipes as the only means of waterproofing at hand. Then, perhaps, in getting over or under some other man's line of pipe we either broke it and had to stop to repair it or else we worked too close to some loose sewer stones and broke through them for another job of repairing.

These were some of the mechanical difficulties, but whatever fate it was that was amusing itself at our expense, it had other methods than these. Imagine the streets shown in the photographs (the weather prevented taking shots of the actual scene of the work) to be lined with the little eight-by-ten shops of an oriental market quarter, with their little display stands on the pavement beside them and with the buyers grouped around, joined perhaps by curious children and not a few curious older people, commenting pleasantly or sarcastically on "the way these Americans do things." Imagine, too, the weather to be the Mediterranean winter with the sort of cold rain that we have here in October or March, gradually making mud out of your little 15-inch spoil bank for the people and the donkeys to spread in a slippery layer over the cobblestones!

At one time, when the rain was heavy and had blocked work for five or six days, with quite a stretch of pavement in bad shape, a young Syrian workman remarked that we'd better be getting something done pretty soon, "For," said he, in his expressive Arabic, "those shop-keepers are already cursing us with curses each one so long," and he held his arm outstretched.



View of a Sidon Street.

It was with considerable relief that we made the final connection to the tanks in the other school, opened everything wide and watched a good stream slip out the end of the pipe. There was some anxiety even then, however, for the new string of pipe for city water wouldn't drip a drop! We found that the water had been shut off for a day or so because of the

heavy rains that muddied the river. So we waited till it was turned on and still no flow. By opening a plug at a low point we found that the pipe carried water but could not get it at the usual height of delivery. After trying various means we made a long plunger with a light rod and two or three leathers and some nuts, and worked it up and down in the inlet at the stand-pipe till we had pumped the air bubble, which was evidently causing the trouble, out of the way and got a flow.

Of course the rams had been at work some years before this and there were perhaps one or two others in the country, but except for the regular English water-works plant in the large city of Beirut, some twenty-five miles away, this little air-engine constituted the only intra-urban, artificial power water works in all that part of the country. The ram, too, described at the outset, though in very common use, would seem, so far as the writer's knowledge goes, to be quite unique in having its source, its active parts, and its waste water run-off all below the surface of the ground from twenty to forty feet.

Innumerable incidents of both technical and general interest could be told out of the year's experience and of the experience of three previous years, but those given will afford a glimpse of one feature of this curious, new-old country, where American educational effort has wrought a peculiar combination of the habits and speech of two thousand years ago with the newer thought and industrial methods of the West.

THE HIGH-TEMPERATURE ELECTRIC RESISTANCE FURNACE.

BY H. RALPH BADGER.*

In three important factors the electric resistance furnaces are fundamentally superior for most industrial operations that come within their scope; first, in the quality of heat they produce; second, in the distribution of heat throughout the working chamber that is possible with them; and third, in the means of temperature regulation they possess.

As to the first, "electric" heat, as developed by electrical resistance, is in effect quite different from the heat produced from such other sources of energy as coal, oil or gas, in that it is not the result of the process of combustion. With all of these latter sources another element, the "supporter of combustion," is of course absolutely essential. The very presence of this oxidizing agent is for most purposes detrimental to the quality of the finished product in hand. Such a depreciating condition is entirely unnecessary to the development of even high temperatures by electrical resistance, where no chemical changes are required whatever.

That a more desirable distribution of heat, whether uniform or definitely varied, is possible throughout a working chamber heated by means of electrical resistance than in those heated by combustion, of any fuel, is largely due to a mechanical advantage. In the former, the heat is generated in the actual material of the resistor, while in the latter it depends upon a process. The material of an electrical resistor can in general be arranged to better advantage in the structure of a furnace, for producing the desired heat distribution, than can the mechanical equipment necessary to carrying out the process of combustion (regardless of the fuel).

The regulation of temperature in the electric furnace is dependent practically upon but one thing, i. e., the energy supplied. While this is mechanically not as simple to control as in "combustion" furnaces, it at the same time can be more uniformly varied. Again, these latter furnaces are complicated by further conditions, viz., the supply of the "supporter of combustion" must be controlled, as this too influences the temperature, and, disposal must be made of the "products of combustion" resulting from their operation.

Recognizing from these fundamental principles, the advantages of electrical operation, a line of Electric Resistance

*Class of 1907. With the Hoskins Manufacturing Company, Detroit, Mich.

Furnaces has been developed for application chiefly to the industrial operations involving the heating of metals and metallic parts to high temperatures.

Obviously the material of the "resistor" adapted for such furnaces must successfully resist the action of the temperatures it is desired to produce. Graphite or carbon was chosen, having the desirable properties of reasonable mechanical strength and comparative low cost, in addition to its very high refractory powers. As heat is produced in these furnaces by supplying electric energy to their resistors, their temperatures may be altered by varying the quantity of energy so supplied. With a constant voltage this is accomplished naturally by varying the resistance of the working circuit, which is carried out by having the resistor made up of a number of carbon strips. Increasing the mechanical pressure on these, that is, by forcing them closer together, their resistance as a circuit is lessened and they draw more current, with resulting rise in temperature. Lessening the pressure on the strips, the reverse takes place. This is the familiar principle of the carbon-plate rheostat, though in the furnace carried to a degree hardly suggested by the other.

A point to be noted is that in the furnace itself the means of temperature variation is completely within the working chamber, so that the change comes exactly where the resulting effect is desired. This is an important efficiency consideration in each of the following designs of the Electric Resistance Furnace produced under the patents of Albert L. Marsh by the Hoskins Manufacturing Company.

Crucible Design Furnace

The chamber walls constitute the heating unit and consist of two series of carbon plates in contact ("**a**" and "**a**," Fig. 1) and the graphite end-blocks "**b**." These are under a slight longitudinal pressure from the electrodes "**c**," which are also of graphite. Under even "ten-hour-a-day" operation a set of carbon plates will last over a week, the end-blocks two weeks to 15 days, and the electrodes a month or more. Renewal of these parts is obviously very simple.

At the terminals "**e**" the low-voltage current is supplied, this being conducted directly to the electrodes through water-cooled blocks "**f**;" "**g**" indicating the inlet and outlet for the running water. The hand screws "**d**" serve as a fine means of regulation of the energy supplied by varying the resistance —and hence the resulting temperature in the chamber.

A thick, highly refractory insulation surrounds the heating-unit walls and separates them from the outer steel casing.

This insulation is both to withstand the high temperatures produced and to conserve within the chamber the maximum amount of heat generated.

The various sizes made of this design operate on from 10 to 30 volts, alternating current being preferable so that these potentials may be obtained by transformers. In a furnace of

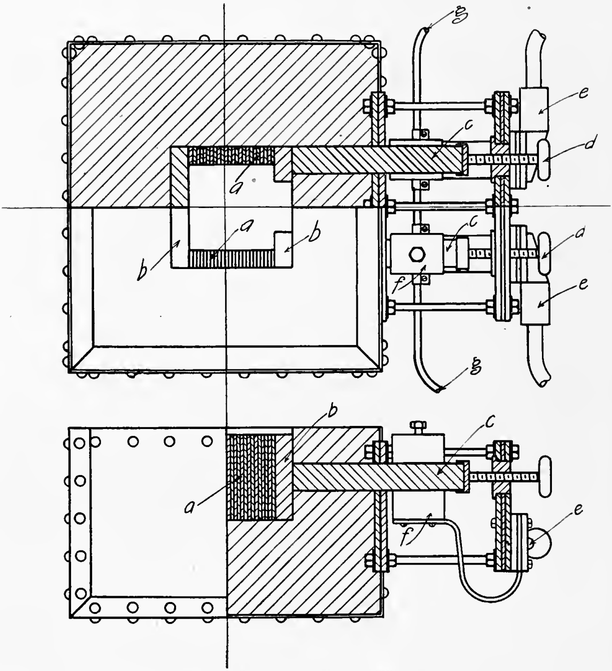


Fig. 1. Crucible Design of Electric Resistance Furnace.

10″x10″x10″ chamber dimensions, a pressure of 30 volts is used. In this size a maximum of 45 k. w. of energy will run the chamber temperature from cold to about 2700° F. in an hour's time. At this point the carbons are of course incandescent. Once attained, such a temperature may be held constant while drawing but 50% of its initial energy. For such a furnace the regula-

tion at any time may be considered as about 60% to 75% of the maximum power consumption.

Temperatures up to 3600° F. may be obtained in these furnaces and due to this high range they are used for melting platinum. In one of the government mints they are applied to the melting down of gold and silver. Other metals such as nickel, iron, copper, brass, steels and various alloys are, in

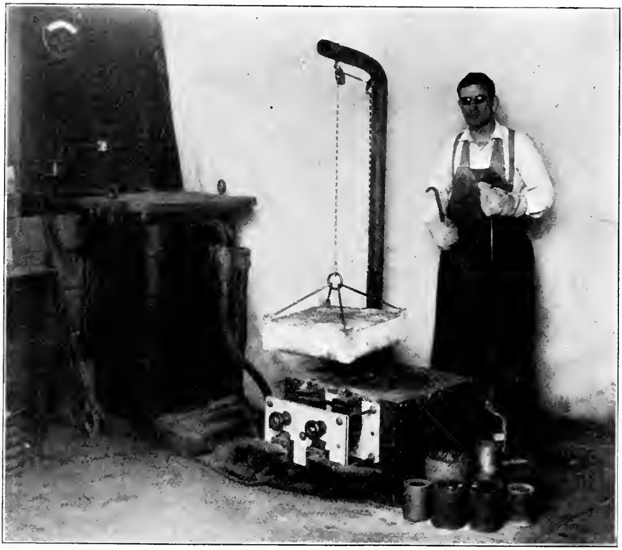


Fig. 2. Crucible Furnace Showing Transformer.

crucible charges, melted in them. They may be used as well for heating barium chloride in steel treating, for heating cyanide and lead baths and for "fire" assay work.

Muffle Design Furnace

Exactly the same principles applied to the "Muffle" form of furnace are illustrated by Fig. 3. In this the carbon plates are in a horizontal position, on either side of the chamber, a graphite block connecting the two series across the top or roof of the chamber. A vertical regulating pressure is applied by

the handscrews which may be seen underneath the body of the furnace.

In this furnace, which is considerably more enclosed than the crucible form, the safe operating temperatures are practically limited to 2500° F., though this is quite high enough for the principal use for which it has been designed, namely, the hardening of steel tools and parts.

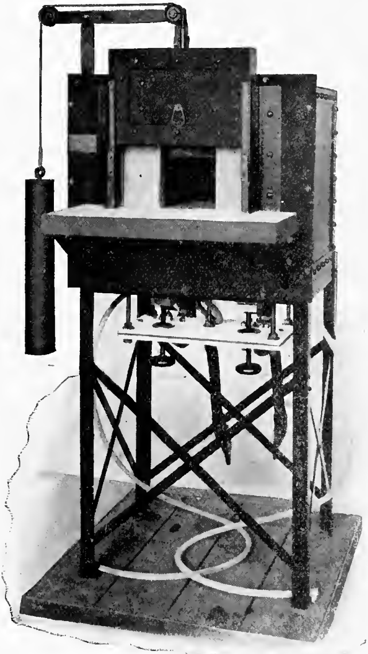


Fig. 3. Muffle Design of Electric Resistance Furnace.

Almost an entirely new understanding is at present working out in a practical way on the subject of heat treatment of various steels. Scientific methods, in place of the customary shop-room guess work, are fast being developed and applied to this very important branch of machine and tool production.

Foremost in this movement is the use of electricity, both to produce the required heat by means of resistance, and to measure its intensity through application of the thermo-couple.

Besides the fundamental advantages of electrical operation already outlined, the electric furnace, shown in Fig. 3—and again as part of the installation in Fig. 4—possesses inherently the desirable quality of an actually **reducing** chamber atmosphere while operating. This is brought about by the great affinity the incandescent carbon walls exert for the slight amount of oxygen that is allowed to enter while raising the door.

Fig. 4. Electric Furnace for Tool Hardening in the Plant of the Link-Belt Co., Chicago.

A working installation is shown in Fig. 4. In this corner of the hardening room of the Link-Belt Company's Plant, the electric furnace is seen to the left of the center; a pre-heating furnace being on its left and an oil bath to the right. The switchboard contains, besides the necessary controlling apparatus for the motor-generator set supplying the current, a pyrometer meter indicating the temperatures of the furnaces, in each of which a thermo-couple is installed.

Tube Design Furnace

A third design of this type of furnace is shown by Figs. 5 and 6. In this the heating unit is composed of carbon plates in the form of rings "**a**," which terminate with graphite blocks, "**b**." The pressure-regulating hand screws are indicated by "**d**;" "**e**" being the electrical terminals and "**g**" the water-cooling connections.

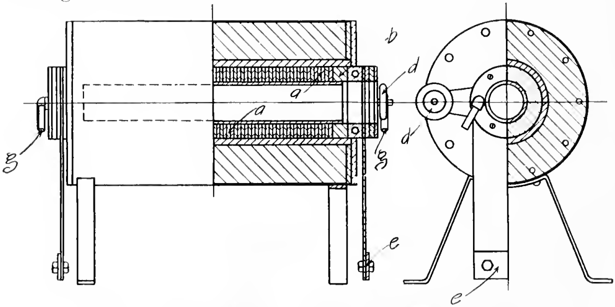


Fig. 5. Tube Design of Electric Resistance Furnace.

Again, due to the enclosed structure, the maximum safe operating temperature of this furnace is about 2500° F. It is used particularly for heat-treating special steel parts such as

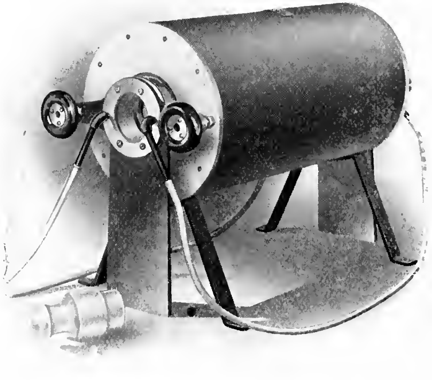


Fig. 6. Tube Furnace Showing Chamber Opening and Adjusting Hand-Screws.

drills, taps and dies; and also for annealing metal tools and rods.

The objective production of heat, as a branch of the electrical industry, while later in line of commercial development than either that of light or dynamic power, nevertheless is growing rapidly in importance. The fundamental advantages of electricity as a form of working energy are commanding for it the same considerations that are now so widely recognized in the other branches of the art.

THE MEASUREMENT OF TEMPERATURE.

BY JAMES CLINTON PEEBLES, E. E.*

It is the purpose of this paper to discuss some of the devices which are in use for the measurement of temperature, with special reference to the measurement of comparatively high temperatures, from about 500° F. up. Also, the errors to which such instruments are subject will be pointed out, and so far as possible, methods of avoiding these errors will be indicated.

The Mercurial Thermometer

The instrument in most general use for the measurement of temperature is the mercury-in-glass thermometer. Other liquids than mercury are sometimes used in a glass thermometer, but the principle is the same. When such an instrument is used at a temperature of 500° F., or higher, it becomes subject to errors which are often considerable, and which the simplicity of the instrument tends to conceal.

The most common source of error in such a thermometer is boiling of the mercury, which may occur at as low a temperature as 300° F. This produces a vaporization of a portion of the mercury, with a subsequent recondensation in the upper, cooler part of the capillary tube. This trouble can be overcome by introducing an inert gas, such as nitrogen, into the capillary tube above the mercury. As the mercury rises in the tube upon an increase in temperature, the gas pressure is increased and the boiling of the mercury thus prevented. This precaution is observed in the higher grade thermometers, but instruments are on the market which are subject to a considerable error from the boiling of the mercury. When using a thermometer which has not been filled with nitrogen, a good precaution to observe is to keep the top of the mercury column as cool as possible, and so prevent boiling, or to keep the whole stem hot, which prevents condensation of the mercury. This precaution will be effective up to 350° to 400° F., but for higher temperatures a nitrogen filled thermometer should always be used.

After a thermometer has been made and calibrated it may undergo certain changes which will very seriously affect its accuracy. The most important changes, and the only one which need be considered here, is a permanent contraction of

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*Class of 1904, Instructor in Experimental Engineering, Armour Institute of Technology.

the glass which renders all the readings of the instrument high. This is caused by a slow readjustment of the internal stresses in the glass which were produced when the stem was made. Tests made by the writer have shown thermometers to read as much as 60° high at a temperature of 700° F., due to the contraction of the glass. Errors of this magnitude were found in supposedly high grade instruments, much above the average thermometer to be found in the market. It is quite probable that many thermometers in general use, the indications of which are accepted as correct by the users, would be found on test to be subject to errors even greater than this.

In the manufacture of the best thermometers the glass stem is annealed before the scale is etched on. This is done by heating the stem at a temperature somewhat above the highest at which it is to be used, and maintaining it at that temperature from 5 to 10 days. It should then be cooled very slowly, the cooling lasting from 4 to 6 days. This removes all the strains from the glass and produces a thermometer which will not change with age. In buying a thermometer for use in work where reliable indications are essential, only one which has been properly annealed in the making should be considered. Many thermometers which have not been thus artificially aged are in the market.

In perhaps the majority of cases where a thermometer is used, the bulb is placed in contact with the object of which the temperature is desired, while a considerable portion of the stem emerges into a very different temperature. For example: Suppose an experimenter wishes to determine the burning point of a sample of gas cylinder oil. The bulb and perhaps a small portion of the stem are immersed in the oil at a temperature of say, 650° F. The greater portion of the stem emerges into the air above the oil bath, the average temperature of which may not be much above 100° F. Most high grade thermometers are calibrated under a condition of total immersion, and are correct for that condition only. When only the bulb is immersed and the stem emerges into the air at a much lower temperature, the indications of the instrument will be considerably in error. The amount of the error will depend upon the difference in temperature between immersed and emergent parts, the number of degrees on the emergent stem, and the glass of which the stem is made.

Stem correction $= K n \, (T^\circ - t^\circ)$, where K is a constant depending on the glass, n is the number of degrees on emergent stem; T° is the temperature of the immersed part, and t° the temperature of the emergent part. The value of K must be

determined experimentally for each thermometer, as it differs for different glass. This can be done by comparing the reading of the thermometer when exposed to a given temperature under a condition of total immersion with the reading under a condition of partial immersion. This gives all the factors in the above equation except K, which may therefore be calculated.

In the thermometer mentioned above in connection with the test of cylinder oil, the value of K is .00009. The oil is at a temperature of 650° F., and the air above the bath at 100° F. Hence T°—t°=650°—100°=550°. Assume that the stem is immersed in the oil to the 50° point. The stem correction is

$$0.00009\ (650-50)\ (650-100) = 29.7°.$$

When the stem is colder than the bulb the stem correction must be added to the observed reading. Hence, the correct burning point of the oil is 650° + 29.7° = 679.7°. When the stem is hotter than the bulb the stem correction should be subtracted.

A reliable mercury-in-glass thermometer should be well annealed to prevent slow contraction of bulb and stem with age; the upper part of the capillary tube should be filled with nitrogen to prevent boiling of the mercury; and the stem correction should be known.

Resistance Thermometer.

The practical limit of a mercurial thermometer is from 800° F. to 900° F. Above this it is very difficult to obtain reliable results with a mercurial thermometer, and so some other method becomes necessary. The electrical resistance of the metals is known to change with temperature, and since electrical resistance can be measured with considerable accuracy this furnishes one of the most reliable and accurate methods for the measurement of temperature.

Platinum is practically the only metal which has come into general use for this purpose on account of its high melting point and resistance to the attack of gases at high temperatures. The first electrical resistance thermometer was designed by Sir William Siemens, and was later improved and perfected by Callender and Griffiths. Siemens' instrument was made by winding fine platinum wire on a fire clay cylinder and surrounding it with a protecting tube of porcelain or quartz. This thermometer was found to be sluggish in its

action, requiring considerable time to come to the temperature of the surrounding medium. It gave very good results, however, where the temperature was nearly constant, as would be the case in an annealing furnace.

In Callender's instrument the platinum wire was wound on a strip of mica and surrounded with a steel tube. The porcelain tube is very fragile and was found to break with the slightest blow when hot. It is also very likely to crack when exposed to sudden changes in temperature, and hence cannot be used with success in a metal bath. The Callender instrument, with steel protecting tube, was found to be quite sensitive and extremely accurate. In fact the resistance thermometer is probably without doubt the most accurate instrument that we have for the measurement of temperature. It is a matter of record that a thermometer of this type, designed and constructed by the United States Bureau of Standards, reached the temperature of the surrounding medium to within 1/1000 of a degree Centigrade in three seconds.

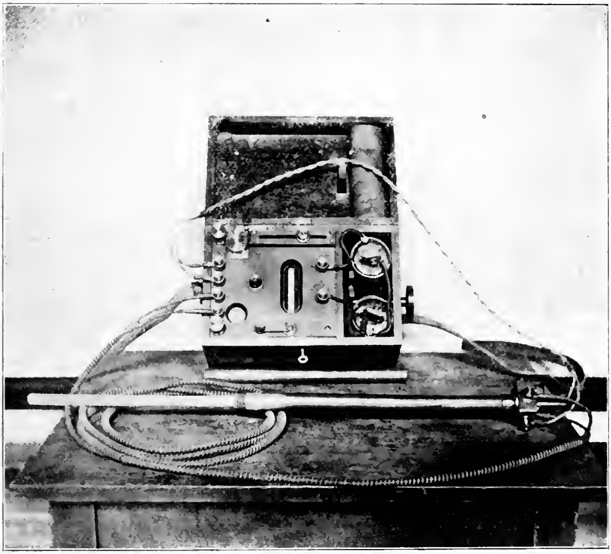

Fig. 1. Whipple Indicator with Resistance Thermometer.

The measurement of the resistance of the platinum coil is an important point in resistance thermometry. The Wheatstone bridge method is the one usually employed, involving the use of a galvanometer, an adjustable resistance and a battery. The operation consists in adjusting the variable resistance in one branch of the bridge until a balance is obtained, indicated by a zero reading of the galvanometer when its circuit is closed. A certain amount of manipulation is therefore always necessary to secure a temperature reading with a thermometer of this kind. Hence a resistance thermometer is not a directly indicating instrument, unless the necessary manipulation is done automatically.

A well known form of instrument for use with a resistance thermometer is a Whipple Indicator. This instrument is shown in Fig. 1, connected to the thermometer and ready for use. It consists of a Wheatstone bridge, battery and galvanometer, contained in a single case as shown. The adjustable resistance consists of a coil of wire wound upon a drum which is revolved by hand until a balance is obtained. Since the temperature sought depends upon the resistance of the platinum coil in the thermometer, and since this in turn is equal to or proportional to the adjustable resistance on the drum, at the time a balance is obtained, it follows that the temperature scale can be placed directly on this drum. Thus it is that instead of reading the resistance which has been wound upon the drum we read the temperature directly.

Of course certain known points must be located on this temperature scale, in order to make possible the step from resistance to temperature. The freezing points of certain of the metals are known with a considerable degree of accuracy, and this supplies a convenient and reliable method for calibrating an instrument of this kind.

Resistance thermometers are made in various sizes and lengths, up to one inch in diameter and about thirty inches in length. The platinum resistance coil usually occupies not more than four inches in the lower end of the protecting tube, from which platinum leads are run to binding posts on the boxwood head at the other end. It is important that no change in the resistance of these leads, due to temperature changes, should affect the measurement of the resistance of the thermometer coil. For this reason two compensating leads of the same size and length as the true leads, are placed side by side with the latter, and connected to two separate binding posts in the boxwood head. Any change in the resistance of the true leads is balanced by an equal change in the com-

pensating leads. All that remains to be done is to connect the compensating leads to the adjustable resistance of the Wheatstone bridge. Thus any change in the resistance of these leads simply adds to or subtracts from the adjustable resistance in exactly the same magnitude as a change in the resistance of

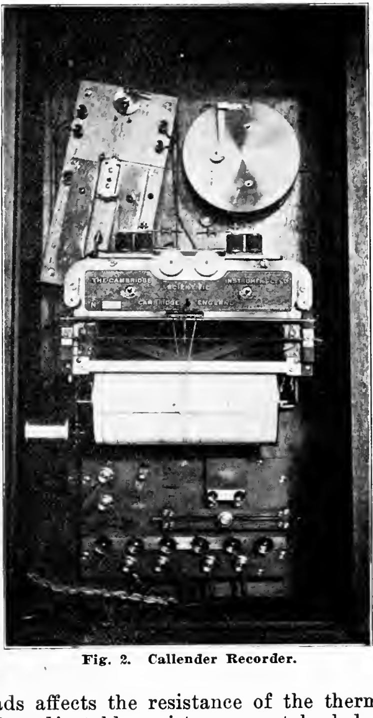

Fig. 2. **Callender Recorder.**

the true leads affects the resistance of the thermometer coil.

Since the adjustable resistance must be balanced against the thermometer coil when a reading is obtained, it follows that the changes in lead resistance are eliminated. Thus an instrument of this kind becomes independent of the depth of immersion, a very important point in high temperature thermometry.

A very excellent instrument for use with a resistance thermometer is the Callender Recorder, shown in Fig. 2. This instrument gives a continuous record of temperature, the chart covering a period of twenty-four hours. In this recorder the adjustments of the Wheatstone bridge are made automatically by means of magnets and clock work. Two magnets are made use of, one operating when the current through the bridge is in one direction and the other when the current is in the opposite direction. The adjustable resistance is operated by the clock work, the magnets simply serving to release a brake which holds the clock in check. The clock operates the adjustable resistance in one direction or the other, according to which magnet has operated. As soon as a balance is obtained the current ceases to flow through the magnet, which immediately lets go of the brake and stops the clock motion.

Thus, all the manipulation necessary for a measurement of resistance is done automatically and the instrument will give a continuous record of temperature.

Up to about 2200° F., the platinum resistance thermometer gives the most accurate measurement of temperature that we have. The only objections to it are a slight change in the resistance of the platinum with time, and the fragile character of a porcelain or quartz protecting sheath.

Thermoelectric Thermometer

When two dissimilar metals are fused together and the junction heated, the latter becomes a source of electromotive force. The magnitude of this electromotive force is proportional to the temperature to which the junction is raised. This fact offers a simple and convenient method for the measurement of comparatively high temperatures.

Such a junction of two different metals is known as a thermo-electric couple, and much study and investigation have been devoted by physicists to the thermo-electric measurement of temperature. The credit for finally placing thermo-electric pyrometry on a satisfactory basis belongs to LeChatelier. He made a couple consisting of one wire of pure platinum and the other an alloy of 90% platinum and 10% rhodium. This is known as the LeChatelier couple and is the one in general use at the present time.

In the commercial application of this principle, the two wires forming the couple are first fused together, and then are insulated from each other throughout their length by winding asbestos thread upon them. Each wire is then run

through a small porcelain tube, the tubes extending almost to the junction. The whole is then covered by a large porcelain or quartz tube, and the two free ends of the wires led to binding posts on the wooden handle or socket to which the enclosing tube is fastened. A millivoltmeter graduated to read temperature in degrees completes the apparatus.

The magnitude of the electromotive force produced by such a couple depends, not upon the absolute temperature of the junction, but rather upon the difference in temperature between the junction and the other ends of the wires, where they are connected to the external leads. Hence, we have the terms "hot junction" and "cold junction" to designate the different ends of the wires forming the couple or "element." It is important, therefore, that the cold junction be kept at a constant temperature while the thermo-couple is in use. Neglect of this precaution may lead to considerable error in the indications of the instrument.

In addition to its simplicity and ease in handling, the thermo-electric pyrometer has the advantage of a very small time lag. It comes quickly to the temperature of the medium in which it is placed, and hence is suitable for measuring changing temperatures. In this particular it is superior to the resistance thermometer, but is not capable of such great accuracy as the latter instrument.

The sensibility of a platinum-rhodium thermo-couple diminishes rapidly below 500° F., and hence, it is not suited for measuring comparatively low temperatures. In the range between 300° F. and 900° F., the best results are obtained from the use of a couple of copper and constantan or iron and constantan. Such a couple gives a much greater electromotive force in this range than can be obtained from a platinum-rhodium couple, and hence is more satisfactory.

All metals disintegrate more or less when exposed to high temperatures for a considerable length of time. This disintegration of the metal forming a thermo-couple is also accompanied by a loss in electromotive force, and hence after long exposure to a high temperature, the indications of such a couple are likely to be somewhat in error. If platinum be kept at a dull red heat (about 1800° F.) for eight hours it will suffer a loss of about ½% in electromotive force. Continued heating will not increase this loss materially, and when it is considered that all other metals suffer a much greater loss, it is easily seen that platinum is by far the best metal for a thermo-couple.

Optical Pyrometers

There are many industrial processes carried on at temperatures where platinum either disintegrates rapidly or fuses. Such temperatures are to be found in the electric furnace, which now has a wide commercial application. Manifestly none of the temperature measuring devices discussed thus far, as electric resistance and thermo-electric pyrometer, are suitable for use with such high temperatures.

For some time it had been the custom to estimate these temperatures by the trained eye of the experienced workman. But this method was only approximately correct at best for the same eye may vary considerably in the estimation of color. This crude method, however, furnished the clue to the discovery of a much more accurate and scientific method, whereby the temperature of a hot body is measured by the intensity of the light which it radiates. An instrument for measuring temperature by means of light radiation is known as an optical pyrometer.

The principle upon which optical pyrometry is based is known as the Stefan-Boltzmann radiation law. These two physicists, after much study and research, succeeded in establishing the physical law that the total energy of radiation from a hot body is proportional to the fourth power of its absolute temperature. The research from which this law was deduced is discussed by Waidner and Burgess in Bulletin No. 2 of the United States Bureau of Standards.

It will be evident that if it is possible to measure the total energy of radiation with a fair degree of accuracy, we immediately have a very accurate measure of temperature, because the latter is proportional to the fourth root of the energy of radiation. Thus a considerable error in the measurement of the total energy of radiation will give a very small error in the determination of the temperature.

Photometric methods have been made use of for the purpose of measuring the intensity of the light radiated from an incandescent body, and along this line the optical pyrometer has been worked out. The method consists in comparing the intensity of the light from the hot body with that from a standard lamp, by ordinary photometric methods.

One of the best optical pyrometers is the invention of LeChatelier, the man who did much in the development of the thermo-electric pyrometer. Inasmuch as the principle used in this instrument is typical of all others, it will be described rather carefully, from which it should be possible to obtain a fair idea of the optical pyrometer in general.

The construction of the instrument may be seen from Fig. 3. A small gasoline lamp is placed at A, so that light from its central portion passes through the lense B, is reflected from the 45° mirror, brought to a focus by the eye-piece, and observed through a red glass.

This provides a red comparison field of constant intensity. The lamp A is mounted eccentrically, and may be turned so that the image of the flame is exactly bisected by the edge of

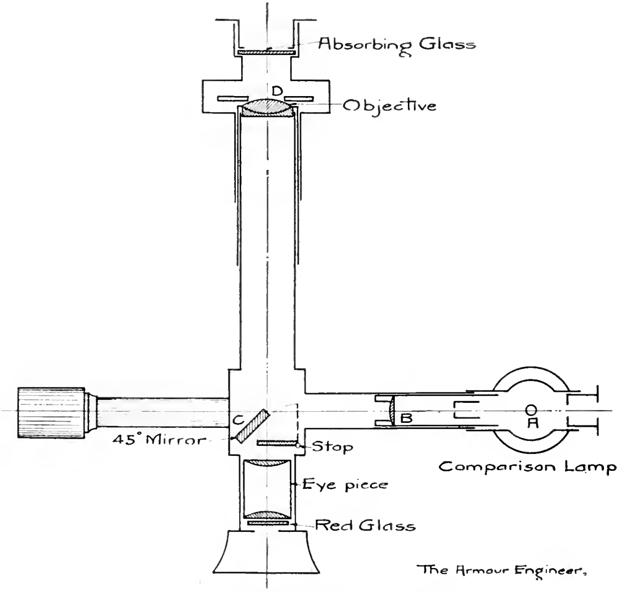

Fig. 3. LeChatelier Optical Pyrometer.

the mirror C. Light from the incandescent body under observation is focused by the objective, passes by the edge of the 45° mirror, and forms a red field immediately beside and touching the first.

A measure of temperature is made by bringing the two red fields to the same brightness. This is done by opening or closing the iris diaphragm D in front of the objective, thus

admitting more or less light from the body whose temperature is sought. For very high temperatures additional absorbing glasses of known coefficients of absorption, are placed below the objective, and for lower temperatures before the comparison lamp. The opening of the iris diaphragm, when equal intensity has been established, is read upon a scale, the square of whose reading is a measure of the intensity of the light from the incandescent source.

Since, according to the Stefan-Boltzman law, the temperature is proportional to the intensity of the radiation, we have immediately a measure of the temperature when we have measured the intensity of the radiation. All that is necessary is to have two sources of light of known temperatures, molten metal for example. Note the reading of the pyrometer when focused upon each of these bodies and plot two points having for their co-ordinates temperatures and scale reading on the iris diaphragm. Draw a straight line through these two points, produced in both directions, and the pyrometer is calibrated for all temperatures.

There is one important point to be kept in mind in connection with the Stefan-Boltzman law quoted above. The law is true only for what is technically known as a "black body." The conception of such a body is due to Kirchhoff, who defined it as a body which would absorb all radiations falling on it and would neither reflect nor transmit any. Kirchhoff pointed out that the radiation from such a body is a function of the temperature alone, and hence may be used to measure the temperature. The first experimental realization of such a "black body" was made by Wein and Lummer, who heated the walls of a hollow opaque inclosure as uniformly as possible and observed the radiations coming from the inside through a very small opening in the walls of the inclosure.

It is evident that such a body will absorb all the radiations incident through the small opening, no matter what the material of the walls may be, for unless the walls are **totally** reflecting, all radiations must sooner or later be absorbed, except that portion which may again escape through the small opening. The presence of this small opening makes a slight departure from a theoretical black body.

No body is known whose surface radiation is that of a black body. The radiations from carbon and iron are very close to black body radiation, while the radiation from polished platinum and the white oxides departs very evidently from it. It follows, therefor, that a number of different bodies all heated to the same temperature will radiate different amounts of

energy, and hence the optical pyrometer would show temperatures for them all. In this connection the term "black body temperature" has come into use. Two bodies are said to be at the same black body temperature when they radiate the same amount of energy. Manifestly they are not at the same temperature, and hence the term, black body temperature violates the conception of equal temperatures which is based upon thermal equilibrium between the two bodies if brought into contact.

Nevertheless, when pyrometers are calibrated in terms of black body temperature, as all instruments based upon the Stefan-Boltzman law must necessarily be, the conception of equal black body temperatures is of great practical value.

It will be evident from the foregoing that the optical

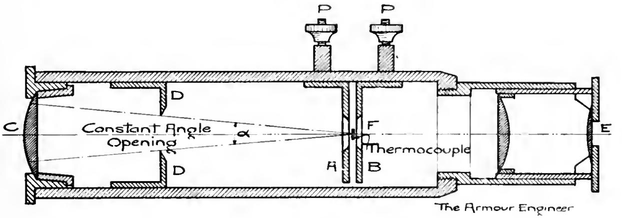

Fig. 4. Féry Thermo-electric Telescope.

pyrometer cannot be depended upon to give the correct absolute temperature of all bodies. It will, however, repeat its indications upon the same body with unerring accuracy, and in a large number of industrial operations this is all that is required. After the proper temperature for any operation has been discovered, the optical pyrometer will make it possible to duplicate this temperature day after day with great accuracy.

There are a large number of operations where the radiation differs but slightly from that of a black body and hence the optical pyrometer will read the absolute temperature correctly. A boiler furnace, a steel furnace, a porcelain kiln, a pot of molten glass, an electric furnace, hot fire brick, etc., are examples. Thus the optical pyrometer has a wide field for usefulness in the mechanic arts.

One of the most convenient instruments, based upon the energy of total radiation, is Fery's Thermo-electric Telescope.

This instrument combines the thermo-electric and optical principles in the measurement of temperature in that its indications depend upon the energy or radiation and are obtained from a thermo-couple and galvanometer. The construction is shown in Fig. 4. Radiation from the incandescent body passes through the lens C and falls upon a very small and sensitive thermo-couple shown at F in the sketch. A diaphragm D D fixed in size and position, gives a cone of rays of constant angular aperture, independent of the distance from the incandescent body. These rays, falling on the thermo-couple, produce an increase in temperature proportional to the total energy of radiation, which in turn induces an electromotive force proportional to the energy of radiation. Thus a direct reading is obtained upon millivoltmeter which, according to the Stefan-Boltzman law, may be read in terms of temperature. The leads from the thermo-couple are led to the binding posts shown at P P in the sketch, to which the millivoltmeter leads are also connected. A and B in the sketch are screens placed on each side of the thermo-couple to exclude all light except that which comes from the incandescent source under observation. E is the eye-piece by means of which the image of the light source is focused on the thermo-couple.

An instrument of this kind is independent of the distance of the incandescent body, within certain limits, as will appear from the following considerations. If the instrument is sighted on an incandescent body of limited dimensions, the amount of radiation passing through the opening in the diaphragm D D will vary with the distance from the hot body, being inversely proportional to the square of the distance. If the thermo-couple were of such size as to receive all of the radiation converged upon it by the lens C, then the indications of the galvanometer would decrease as the distance from the incandescent source increases. But the thermo-couple, however, is not large enough to receive all of the radiation converged towards it. The image of the source of light, formed by the lens C is large enough to overlap the thermo-couple on all sides, so that when the observer sights the instrument the thermo-couple appears as a dark disc in the center of a bright field of light. When the instrument is brought nearer to the source of light, thus increasing the size of the image produced, the only effect is to increase the amount of this overlapping, while the thermo-couple receives no more radiation than before. On the other hand, however, if the instrument be withdrawn to such a distance from the source of light that the image formed is not large enough to completely cover the

thermo-couple, the readings obtained will be too low, and will become less as the distance from the source of light is increased.

From the foregoing it will be evident that the instrument is independent of distance only within certain limits. The image of the incandescent source must always be large enough to completely cover the thermo-couple. In general, the diameter of the hot body should measure as many inches as the distance from the instrument to the hot body measures yards.

The Fery pyrometer is best adapted for use in the range from 1300° F., to 2800° F., where its indications are sufficiently accurate to answer all requirements of industrial work. It should not be forgotten, however, that an optical pyrometer depending for its reading upon a measurement of the energy of radiation reads black body temperatures, which in some cases may vary considerably from true temperatures. But when the same temperature is to be repeated time after time in the same process, the Fery pyrometer will repeat its readings with a degree of accuracy sufficient for all practical purposes.

THE ELECTRIC DRIVING OF ROLLING MILLS.†

BY WILLIAM T. DEAN, E. E.*

The recent successful development of internal combustion engines in large sizes suitable for use with blast furnace gas has directed the attention of steel works engineers and managers to the possibility of electrically driving all the machinery in such plants.

So few years have elapsed since the electrical department of most steel plants consisted of a chief electrician and one arc lamp trimmer, that the growth of the electric drive has been almost incredible. Today contracts are being carried out involving the complete electrical operation of mills to produce 100,000 tons of rails per month, where the motor units reach the enormous output of 10,000 horse-power each.

In this country, the Edgar Thomson works of the Carnegie Steel Co. has the honor of using the first heavy rolling mill drive by electric motors. The system used in this mill (250 volts direct current) is probably the most expensive in first cost and least economical in operation that could have been selected, nevertheless, the installation has been a notable success from the beginning. It is quite probable that the transmission line for the light rail mill at the Edgar Thomson works cost as much as the two 1,500-horse-power direct-current motors used, and the building for housing the starting and speed controlling rheostats would accommodate a very fair boiler plant.

The first consideration in any particular case involving electric drive is—will it pay? Can more steel be turned out for a given cost, or the same steel for a lower cost than with a steam driven mill? The next question is—will the electric motor meet the severe requirements of steel mill practice such as continuous operation 24 hours per day and 30 days per month, will it withstand severe overloads even to the point of stalling, will the serious mechanical shocks incident to rolling, destroy bearings and deteriorate insulation to such an extent as to render the maintenance cost of such machines prohibitive? The comparative costs will be taken up later. All the questions that arise affecting the adaptability of the motor for rolling mill operation have been asked and successfully answered in the past as applying to less important machinery. The solution of the problem from the electrical manufacturer's standpoint is

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†An article published in THE IRON TRADE REVIEW.

*Class of 1900. District Manager, Power and Mining Dept., General Electric Co., Chicago.

only one of degree and therefore rests with the designer. That the many problems entering into the design of the successful mill motor can be solved is evidenced by the mills now being operated electrically and by those undertaken on so great a scale by the United States Steel Corporation.

The ability of a motor to operate continuously at a given load is only limited by its ability to radiate the heat in which the relatively small energy losses appear.

Constants of electrical design, such as safe amperes per square inch in copper conductors, and flux densities in laminated steel, are well known to the electrical designer by years of experience. Generators of as great capacity as the largest motors contemplated, have already been designed, built, and are in successful operation. It may be conceded then with reference to continuous operation, that no serious difficulties will be encountered. The electric motor has a great advantage over the steam engine in the matter of performance under overload. Speaking of the induction motor particularly, it may have an overload capacity as great as 2½ times its continuous output and the motor may be brought to a complete standstill by an unusual overload and the current flowing in the motor windings under these conditions may be precisely calculated before the motor is built, and provision made to limit the maximum current flowing to a predetermined value. What is of equally great importance, however, is the fact that the motor current may be automatically controlled so that excessive strains cannot occur.

The only uncommon problem in the design of large mill motors aside from that of mere size is that of mechanical proportions to withstand shock and ordinary wear. It is in this particular that the electrical manufacturer has been obliged to revolutionize all his previous ideas. How well he has profited by the experience of the engine builder may be gathered from the massive construction shown in the illustrations.

Many of the mechanical shocks occurring in rolling operations with steam engines are due to the reciprocating motion of the engine and not to the mill and gears. All such shocks disappear when a motor is used, for one of the motor's most valuable characteristics is its uniform turning moment.

When a mill is driven by a cross-compound or twin-tandem-compound engine the shaft receives its turning moment in four impulses; if the cranks are quartered there are four points in each revolution when only one cylinder, or one engine, if twin engines are used, is effective. Very heavy fly wheels must be provided to overcome this defect, or if the

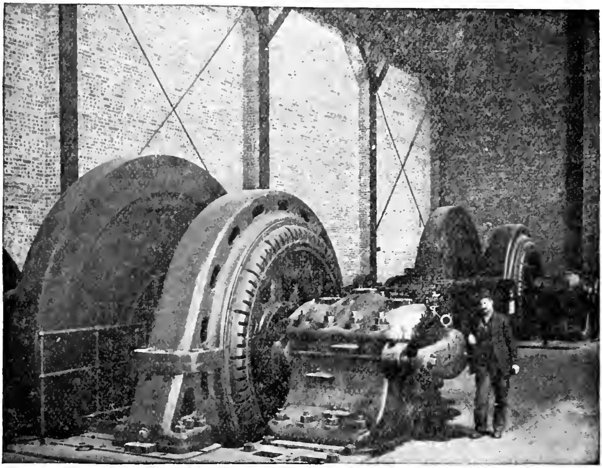
mill is of the two-high reversing type, each cylinder or engine must be made large enough to provide for the maximum torque and there is great probability of entering a slightly cold bloom or ingot at one of the low torque points in the cycle, entailing backing out and loss of time. A motor having uniform turning moment and a maximum torque of 2½ times normal full load torque could experience no such difficulties. Indeed, it would be a very poorly heated bloom that would not pass through the rolls. As a matter of fact, it is necessary to provide automatic torque limiting controllers not to protect the motor but to protect the rolls and gearing between the motor and the steel.

Having outlined the manifest advantages of the motor for mill driving, the cost of operating a steam engine and an electric motor must be compared. Consider a mill requiring an engine or a motor of a given rated brake-horsepower, and assume a non-reversing three-high mill operating practically continuously, conditions most favorable to the steam engine. If steam must be generated on the premises the engine-driven mill will be most economical since the motor must be charged with the cost of transformation from mechanical into electrical energy at the engine and generator, and the cost of transformation from electrical into mechanical energy at the motor as well as the transmission losses. Even the superior economies of large steam turbine generator units will not overcome such double transformation losses. Assume, however, that there is a distant source of power, natural gas, blast furnace gas, coke oven gas, cheap coal or water power, it will be conceded without argument that power may be transmitted more economically electrically than by any other means. It remains to show the relative cost of transmission and the adaptability of the possible sources of power to rolling mill drive.

The internal combustion engine is not adapted to the direct driving of mills on account of its inability to sustain severe overloads and its somewhat instability under widely varying loads. With gas power available the question narrows to the cost of the transmission of gas and the consumption of the same under boilers at the mill, as compared with the utilization of the gas at the source of supply to produce electrical power for transmission to motor driven mills.

In recent blast furnace practice, it has been found that approximately 123,000 cubic feet of gas is produced per 24 hours per ton of pig iron. Two-thirds of this is available for power for the operation of blowing engines and other purposes, the remaining third being used to heat the air blast. A 500-ton furnace will produce therefore 41,000,000 cubic feet

of gas per 24 hours. Numerous tests have shown this gas to have a heat of combustion of 100 B. T. U., or more, per cubic foot. Assuming 90 B. T. U. per cubic foot as a conservative figure the total heat available per 24 hours is 3,690,000 B. T. U. The heat equivalent of one horse-power is 2,545 B. T. U. Therefore, the theoretical power available from the gas is 1,450,000 horsepower-hours, or 60,417 horsepower. Assuming the net efficiency of the gas engine at 22.5 per cent which, if in error, is too high, the total available power from a 500-ton furnace is 13,600 horsepower.



2000 H. P. Three-phase Induction Motor Geared to Two-high Blooming Mills.

On account of the lean quality of blast furnace gas, cylinder dimensions must be large and this has kept the size of single units down to about 3,000 horsepower and generators rated at 2,000 kilowatts are generally used. Such generators have an efficiency of about 95 per cent, making the total electrical energy available per 500-ton furnace, 9,360 kilowatts. Of this power about 600 kilowatts is required to operate gas washing machinery, to pump jacket water, provide exciting current for alternating current generators and minor purposes, leaving a net available power of 9,000 kilowatts. From the figures above we have:

153,750,000 = total B. T. U. per hour.

2,545 = B. T. U. equivalent to 1 horsepower, theoretical

$$\frac{2{,}545}{0.746} = 3{,}420 \text{ B. T. U. equivalent to 1 kilowatt, theoretical}$$

$$\frac{153{,}750{,}000}{3{,}420} = 45{,}000 \text{ kilowatts, theoretical}$$

$$\frac{9{,}000}{45{,}000} = 0.2$$

or the net efficiency of the entire plant will be 20 per cent.

In a large power plant using steam turbine driven generators and every known method of obtaining high efficiency, it has been found that 27,000 B. T. U. in the coal produce one kilowatt at the switchboard. This is under regular commercial conditions and includes all losses such as banking fires, operation of boiler feed pumps, circulating pumps, air pumps, coal and ash handling machinery, etc., and the plant in question is subject to heavy day loads and light night loads. Careful tests at this plant indicate that if the plant could be operated with a constant 24-hour load, such as obtains in steel mill practice, the economy would be 23,000 B. T. U. per kilowatt at the switchboard. In a similar plant, gas fired, but subject to a steady 24-hour load, a still higher economy could no doubt be secured by the use of furnaces, especially designed to burn the gas. Assuming, however, a fuel economy from gas of 23,000 B. T. U. per kilowatt, we have:

$$\frac{153{,}750{,}000 \text{ total B. T. U.}}{23{,}000 \text{ B. T. U. per kilowatt}} = 6{,}685 \text{ K. W.}$$

or with the highest type of plant burning the gas to produce steam and using turbo-generators of large size the power available from a 500-ton blast furnace is 6,685 kilowatts.

As before the theoretical power available is 45,000 kilowatts, giving a net efficiency of 14.8 per cent, or approximately three-fourths the efficiency of the gas engine plant. It should be noted that the higher output of the gas engine plant only

applies to cases where blast furnace gas is available, since in producer gas plants the engine must be charged with the heat losses in the gas producer; moreover, the quality of coal for a gas producer must be much higher than is used in the steam plant, on the economy of which the above calculations are based.

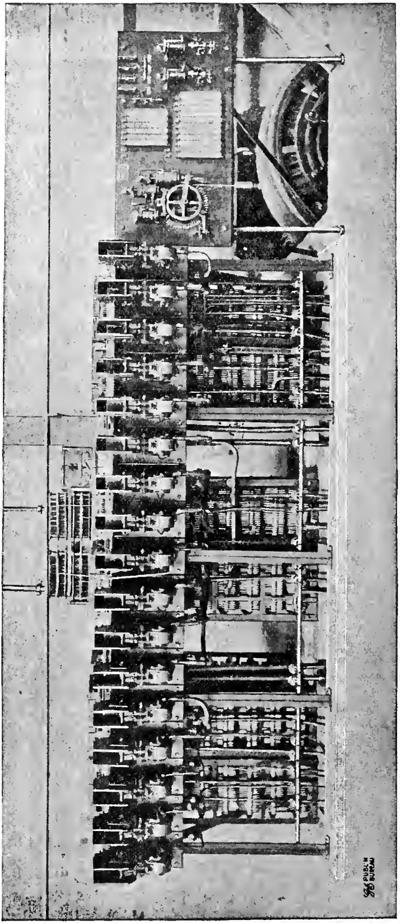
The relative reliability of the gas engine and steam turbine plants must be given serious consideration. A steam turbine plant may be operated at its maximum rating indefinitely with almost absolute freedom from shut-downs or necessity of repairs. The gas engine, on the other hand, has not yet reached a perfection of development where it may be depended upon to operate 24 hours consecutively. In one plant of this nature containing four large engines where in emergency one unit could carry the entire load, an entire shut-down occurred, all four of the gas engines requiring simultaneous repairs. The enormous weights of the reciprocating parts, the great cylinder dimensions, the rapid and wide variation in temperatures combine to make the large gas engine somewhat unreliable. That wider experience will teach engine designers methods of increasing reliability cannot be doubted, and the manufacturers of this class of prime movers are to be congratulated that the great steel interests of the country are willing to invest their capital so as to promote so important a development.

Gas engine builders have made many claims as to the reliability of their apparatus, most of which are based on European practice. To those in possession of reliable data on European practice, such claims are taken with a degree of allowance, as the following quotation from Engineering (London) testifies:

"In this connection we may note that we recently heard of a large continental power station where it has been deemed advisable to install a reserve plant of 200 per cent of the nominal capacity of the station. As opposed to this, some English builders of turbo-generators are advocating the absolute abolition of all reserve whatever, apart from that provided by the by-pass valve, enabling the unit to take, if necessary, an overload of 50 to 100 per cent.

"Certainly the large continental gas-engine may be a success if judged from a non-commercial standpoint. So long as it works, it undoubtedly produces power very economically, but those who have had most experience with them are the very ones who have the longest catalog of their defects."

Early in 1904, contracts were let for gas engines and electric generators of a total capacity of 8,775 kilowatts for Jo-



Secondary Control for 6000 H. P. Induction Motor.

hannesburg, South Africa. It was not until 1906 that power was first delivered and the supply was extremely unreliable.

Quoting from The Engineer:

"On one occasion when five engines of 7,000 horsepower were running, in the space of a quarter of an hour, every man in the engine room but one was rendered unconscious from gas poisoning. * *

At a coroner's inquest held in May (1907) on a gas fatality, it was stated that 63 cases of poisoning had occurred in six months. * *

At last on May 15 the plant was finally shut down. The engine contractors threw up the contract and admitted that they could not get the plant into shape to pass the specified tests. The town council then rejected the plant. * *

In a report dated March 1 last, the general manager stated that owing to continued break-down the whole of the generator sets had never been available for use at one time. * *

The direct current plant of 5,400 kilowatts had had the greatest difficulty in dealing with the maximum load of 2,750 kilowatts, and it had not been found possible to run the alternating current generators in parallel on account of the unsteady running of one of them. The generator sets could not be got to give more than 80 per cent of their normal full load, and it was seldom that two-thirds of the plant was fit to run. For the three and one-half months ended Feb. 28 (1907) the total works cost had been 5.1 cents per kilowatt-hour as compared with the original estimate of 1.72 cents."

A complete turbine plant of large size, including the best machinery, boilers, auxiliaries, etc., and the highest type of station construction can be built for at least 60 per cent of the cost of a blast furnace gas engine plant of the same capacity with its auxiliaries. Assuming as arbitrary figures that a steam turbine plant can be built for \$60 per kilowatt, and that a gas engine plant can be built for \$100 per kilowatt, and that a plant of 40,000 kilowatts average capacity is required, the investment in the turbine plant will be \$2,400,000.

It is to be remembered that the figure for the gas engine plant is undoubtedly low when all the elements are considered and that a turbine plant can be built for \$45.00 per kilowatt where no coal storage plant is required, and further that a turbine plant can be built for \$40.00 per kilowatt where cheap real estate is available. My assumed figure of \$60.00 per kilowatt is based on a complete coal burning plant with coal and ash handling machinery and includes real estate in a great city where land values form a considerable portion of the total in-

vestment. These modifications make a very material difference in the total investment in a large plant, and on this point the showing in favor of a turbine plant is much greater than indicated in this article.

The gas engine plant, however, will require at least 25 per cent excess in capacity in order to maintain the average output given above and many engineers think that in the present stage of the art, 50 per cent excess capacity should be installed. The investment in the gas engine plant will therefore be $5,000,000, or 108.2 per cent in excess of the investment in the steam turbine plant. The interest on $2,600,000 (the difference in investment) at 5 per cent is $130,000 per year, or sufficient to buy 86,750 tons of coal. If this coal were burned under boilers in addition to the gas obtained from the blast furnaces, it would generate 86,750,000 kilowatt-hours or 1,156 kilowatts 24 hours per day, 26 days per month, throughout the year. This figure makes a very respectable addition to the power given above, which may be legitimately expected to be generated by the steam turbine plant, and leaves a relatively small margin of total power in favor of the gas engine plant.

From this showing, the plants depending entirely on gas engines must face very unfavorable conditions. They will have on their hands enormously expensive plants, requiring four or five times as much labor as the equivalent steam turbine plant with constant danger of delay, due to break-downs and with maintenance expenses reaching large figures.

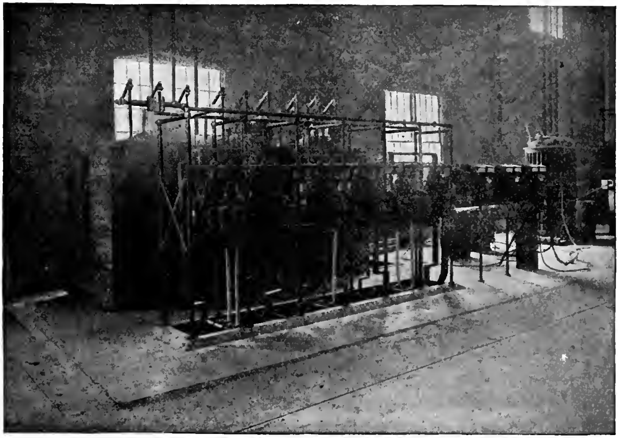
In addition to all inherent disadvantages of the gas engine plant previously noted, the fact must not be overlooked that in the space occupied by one 2,000-kilowatt gas engine generator, a steam turbine unit having a rating of 14,000 kilowatts can be installed with all its accessories, and that a gas washing plant used with the gas engines requires more space than a boiler plant for an equivalent turbine installation. In fact, a gas engine plant with its accessories, requires so much space, both in the engine room and out, that considerable difficulty must be experienced to properly operate all sections as a unit plant.

Earlier in this discussion it was proposed to pipe the waste gases to the rolling mills and there generate steam for the operation of mill engines. Neglecting losses in piping which will exceed the losses in electrical transmission, this system would show a lower economy than the turbo-generator system by the amount that the reciprocating engine falls below the turbine in efficiency. Non-reversing mill engines of large size under favorable conditions, operating condensing, require approximately 14 pounds of steam per brake-horsepower-hour.

Large size turbines only require about 9.4 pounds of steam per brake-horsepower-hour. The total efficiency of such a system would be

$$\frac{9.4}{14} \times 11.15 = 7.5 \text{ per cent.}$$

For purposes of comparison on the mill basis the efficiency figures on the turbo-generator system and the gas engine plant must be decreased by the losses in the mill motor. Such a motor will have a full load efficiency of about 93 per cent.



Primary Control for Three 6000 H. P. Induction Motors.

The relative efficiency of the three systems of utilizing the waste gases are as follows:

	Per cent Efficiency
(1) Gas transmitted to mill to produce steam for mill engine	7.5
(2) Gas burned at source producing steam for turbo-generators, energy transmitted electrically to mill motor	15.17
(3) Gas used in internal combustion engines driving generators, energy transmitted electrically to mill motor	18.6

The above figures should not be taken as absolute but give fairly correct relative values, and clearly indicate the wisdom of motor driving rolling mills. The writer believes that the steam turbine system, while not the highest in efficiency, will provide ample power for all rolling mill purposes. If such is the case, the greater reliability of the steam turbine system far outweighs the lower fuel economy, and the extra investment in a gas engine plant will only pay in case there is a profitable market for the excess power outside of the steel mill proper.

There is another source of electrical power for existing steel plants which is extensively used in Europe but has only been utilized in one case in this country and that on a relatively small scale. I refer to the steam regenerator and low pressure turbo-generator receiving an intermittent steam supply from reversing mills or from non-reversing mills subject to wide variations in load or speed, or both, and delivering a constant supply of electrical energy.

A large reversing engine requires 60 pounds of steam (or more) per horsepower. A steam turbine operating between 15 pounds absolute pressure and 28 inches vacuum requires 45 pounds of steam per kilowatt-hour. Thus, there is available 1.33 kilowatts in electrical energy for each horsepower of such engines, more than enough to operate a duplicate mill electrically. The gain by such an installation is all "velvet" and requires a relatively small outlay of capital.

In choosing a system of transmission and utilization of the electric drive the steel works engineer is at first inclined toward direct current, owing to his greater familiarity with that system and to its apparent simplicity. A direct current system has some advantages such as the extension of an existing plant to care for the heavier requirements of rolling mill drive. However, unless the centers of distribution of the power are very close to the generators, the transmission line will be so expensive as to be prohibitive. If an alternating current system is selected the cost of the transmission line may be reduced to a relatively small proportion of the plant equipment.

A universal formula for copper in a transmission line of whatever system, voltage or frequency is the following:

$$A = \frac{D \times W \times C}{P \times E^2}$$

where A = area per conductor in circular-mils,
D = distance of transmission (one way) in feet,

W = total watts delivered at end of line,
C = constant depending on the system and power factor if alternating current,
P = percentage of loss in power delivered,
E = voltage at end of transmission line.

The constant C has the following values for the various systems employed:

	Value of "C"				
Per cent power factor	100	95	90	85	80
Direct current	2160	....	....	....	....
Alternating current, single phase	2160	2400	2660	3000	3380
Alternating current, 2 phase	1080	1200	1330	1500	1690
Alternating current, 3 phase	1080	1200	1330	1500	1690

As an example in point let us consider the relative cost of transmitting 5,000 kilowatts a distance of 2,000 feet by direct current at 220 volts and by alternating current at the same voltage.

From the above formula:

For direct current

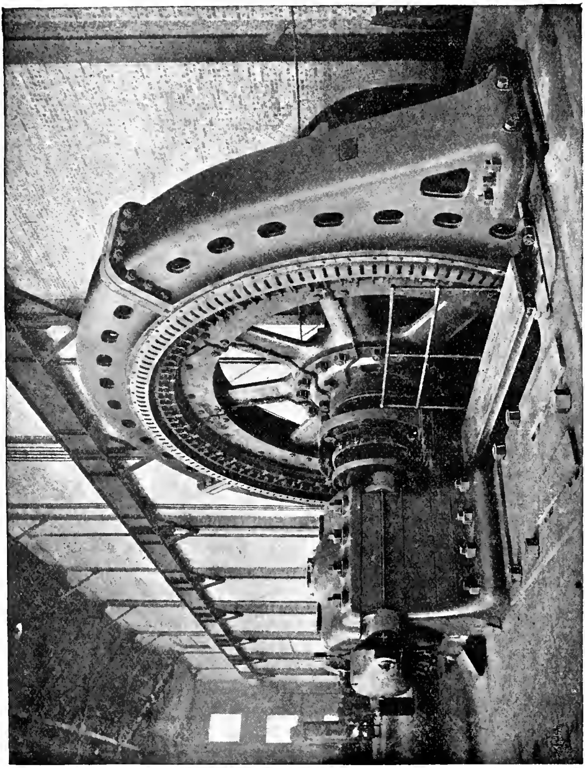
$$A = \frac{2{,}000 \times 5{,}000{,}000 \times 2{,}160}{10 \times 220 \times 220} = 44{,}628{,}100$$

Assuming a loss of 10 per cent, two conductors of this cross section each 2,000 feet long will be required, and since the weight of one foot of copper having an area of one circular-mil is 0.00000302 pound, the weight per foot of the above conductor would be 134.77 pounds, and the total weight of copper required would be 539,107 pounds or over 269 tons of copper, not including insulation. At 20 cents per pound the copper alone for such a line would cost $107,821.40.

For alternating current,

$$A = \frac{2{,}000 \times 5{,}000{,}000 \times 1{,}690}{10 \times 220 \times 220} = 34{,}917{,}024.$$

Assuming the same energy loss as before and a power factor of 80 per cent, three conductors (for three-phase transmission) of this cross section each 2,000 feet long make a total weight of copper of 632,702 pounds, which at 20 cents per pound would cost $126,540.40.



6000 Horsepower, Three-phase Induction Motor.

From the above it is evident that at low power factor and equal voltages the alternating current transmission system would be more expensive than the direct current. By reason of commutation and insulation difficulties, direct current voltages cannot be greatly increased; on the other hand there is no reason why alternating current generators and motors cannot be built to operate at 6,600 volts or even higher and by the interposition of transformers the transmission voltage may even be raised to 100,000 or 150,000 volts.

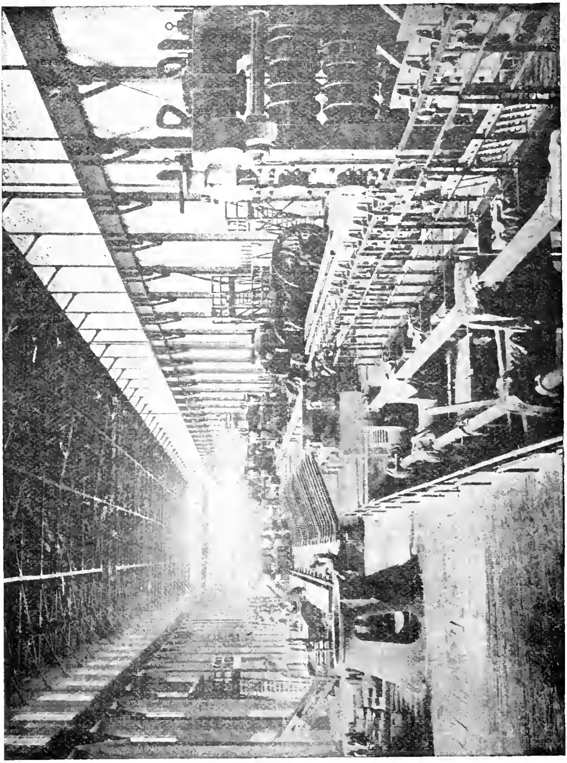
Assuming a transmission at 6,600 volts the area of a conductor becomes:

$$A = \frac{2{,}000 \times 5{,}000{,}000 \times 1{,}690}{10 \times 6{,}600 \times 6{,}600} = 38{,}800.$$

The current per phase for the above 6,600-volt circuit is 545 amperes. It is not safe to allow less than 1,000 circular mils per ampere, hence 54,500 circular mils or more per conductor must be used. The next larger commercial size of wire is No. 2 B. & S. gage, which has an area of 66,000 circular-mils. Substituting this area in the above equation and solving for the value of P we find the power loss to be 5.82 per cent. The three conductors of No. 2 wire would have a weight of 1,205 pounds and would cost $241.80. Thus by using alternating current at 6,600 volts, the cost of copper has been reduced to an insignificant sum and the power loss cut in two. If the power loss were further reduced 50 per cent ,the cost of the copper would only be $323.20. It is true that insulators for 6,600 volts cost more than for 220 volts, still in this case the fewer number required and the greatly reduced labor cost overwhelmingly favor the alternating current high voltage system.

The saving is proportional in all cases. A few summers ago, the writer had occasion to figure on a system involving three 500-kilowatt generators with a transmission of 2,000 feet. The purchaser was offered three 500-kilowatt, 2,300-volt alternating current generators, three 500-kilowatt rotary converters with all necessary switchboards and the copper for the transmission line for a sum about $45,000 lower than he paid for the 250-volt apparatus and line decided upon. The consulting engineer in charge, while an excellent blast furnace man, knew nothing of electrical matters and allowed his client to pay the extra cost for a plant which must sooner or later be remodeled to an economical basis.

Alternating current motors are now offered, which success-



Finishing End of Rail Mill.

fully perform all the functions of direct current motors and have many superiorities, such as absence of commutator and ability to handle extreme overloads. These motors are built in all sizes for the operation of roller tables as well as for the operation of the main rolls, hence, there is no longer an excuse for the direct current system where large powers are used.

The particular voltage to be selected depends on the distance of transmission and the amount of power transmitted as shown by the above examples. Consideration should also be given to the possible expansion of the plant. For a plant generating 10,000 kilowatts or more, 6,600 volts should be the minimum for transmissions of a mile or so. The choice of frequency is limited to 25 or 60 cycles. The lower frequency is preferable, owing to the lower motor speeds obtainable with reasonable cost. The speed of an induction motor is inversely proportional to the number of its poles and directly proportional to the frequency of the source of supply. If the frequency be stated in alternations per minute, the speed will be

$$\frac{1}{N}$$

of the alternations, where N represents the number of poles. Thus, a six-pole 25-cycle (3,000 alternation) motor will have a synchronous speed of 500 revolutions per minute, while a six-pole 60-cycle (7,200 alternation) motor will have a synchronous speed of 1,200 revolutions per minute. The difference in frequency becomes very apparent in large slow speed motors for direct connection to rolling mills.

Such a motor operating at 75 revolutions per minute would have 40 poles if 25 cycle, and 96 poles if 60 cycle. A large number of poles makes a difficult design unless very great diameters are used and in any case has a very bad effect on the constants of the machine, particularly the power factor. Unquestionably a frequency of 25 cycles is preferable for power purposes.

The question of suitable speed for a motor driving a rolling mill should be solved by the mill engineer rather than the motor manufacturer. The former should, however, bear in mind the limitations of speed within which the latter must work. Probably the lowest speed for direct connection to rolls which would be considered would be 50 revolutions per minute for 25-cycle motors. The accompanying table gives the synchronous speeds possible and the probable full load speeds for large 25-cycle motors.

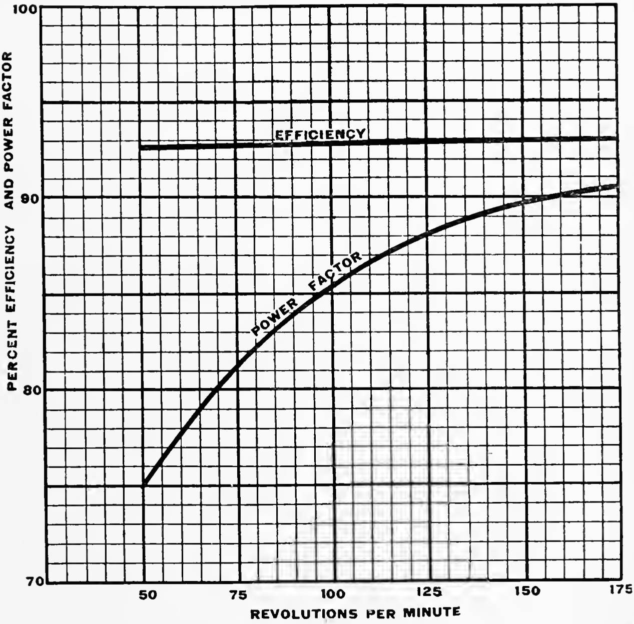
Synchronous and Full Load Speeds for 25-Cycle Motors.

Poles.	Synchronous Speed.	Full Load Speed.
60	50.00	48.50
58	51.70	50.20
56	53.50	51.80
54	55.50	53.80
52	57.70	55.90
50	60.00	58.20
48	62.50	60.70
46	65.20	63.30
44	68.20	66.10
42	71.40	69.30
40	75.00	72.80
38	78.90	76.50
36	83.30	80.80
34	88.20	85.40
32	93.75	91.00
30	100.00	97.00
28	107.10	103.30
26	115.40	111.40
24	125.00	120.60
22	136.30	131.50
20	150.00	144.80
18	166.60	160.80
16	187.50	181.00
14	214.30	207.00
12	250.00	241.00
10	300.00	290.00
8	375.00	362.00
6	500.00	482.00
4	750.00	720.00
2	1500.00	1440.00

Whenever the speed of the rolls exceeds 55 revolutions per minute it is preferable and cheaper to direct-connect the motor than to employ a great reduction. This refers to mills requiring motors of 3,000 horsepower and larger for a single roll stand, and to many cases where smaller motors would be employed. Where it is necessary to drive more than one roll stand from a single motor, thus entailing gearing which would in any case be charged against the mill, a higher speed motor should be used, but in no case should the gear ratio be greater than 3:1. For motors of 2,500 horsepower or larger, a lower gear ratio should be selected.

For a close group of small mills, each of which in succession does a portion of the total work of reducing a bloom to a commercial shape, the most economical drive is by a single motor. This is due to the higher efficiency of a single motor of large size over several small motors and to the fact that such a motor may be operated at more nearly its full load continuously. The first cost of such a plant will be appreciably lower when a single large motor is installed.

The method of driving a group of small mills from a single motor must be very carefully considered in each case. If bevel gears are used the driving shaft must operate at a relatively low speed in order to avoid the use of too high a gear ratio



Curves showing efficiency and power factor of a 5000-Horsepower Motor when designed for various synchronous speeds.

between the shaft and rolls. This means a low speed and consequently an expensive motor. If the conditions will allow the use of a rope drive the motor may have a fairly high speed and the total friction loss may be reduced. It is probable that the maintenance cost of a rope drive for a group of small mills will be lower than for the equivalent bevel gear drive. Any flexible connection, such as a rope drive between the mills and the motor, will be favorable to the operation of the latter. In general it may be said that the higher the motor speed adopted the better will be the efficiency and power factor. This is shown by the curves giving approximate value of power factor and efficiency for a 5,000-horsepower motor designed for various synchronous speeds.

Summarizing the various conditions which must be considered in any proposed rolling mill drive, it has been shown that:

1—The electric drive is absolutely reliable.

2—Alternating current motors and transmission system should be used.

3—A frequency of 25 cycles per second is preferable.

4—With blast furnace gas available the greatest amount of power may be obtained from a gas engine plant.

5—A boiler plant with steam turbines will produce three-fourths the power obtainable with the same fuel used in a gas engine plant.

6—The great reliability of a steam turbine plant outweighs the excessive power obtainable from a gas engine plant.

7—The saving in investment in a steam turbine plant over a gas engine plant is very considerable.

8—It is more economical to generate electric power at the source of gas supply and to transmit same to motor driven mills than to burn the gas under boilers at the mill.

9—The electric drive is the most economical system for every case excepting where coal must be burned under boilers at the mill and in this case approximately double the power can be obtained from a given amount of steam by using low pressure turbines in the exhaust from mill engines.

The writer believes the foregoing conclusions to be correct and that a careful investigation on the part of any steel works engineer will prove their correctness.

THE SAFETY FACTOR.

BY WILLIAM F. DIETZSCH, M. E.*

Paramount to all other considerations in the solution of the innumerable and ever changing problems of the constructing engineer of the present day must be his unstinted regard for maximum safety, reliability, and economy in each and every one of his constructions. Not one cubic inch of excess material can he afford to have his mechanism or structure carry as an unnecessary ballast, in order to conform with the principles of economy; and yet, on the other hand, it should not lack a jot when the reliability of the device and the safety of the users, into whose hands it is placed, is involved. Every element and feature entering into the design of his engineering proposition must be based upon thorough, practical, and scientific study and investigation. He must feel secure in his claim that every dimension in his design has its good and logical "raison d'etre."

Any novel type of engine, boiler, dynamo, bridge, etc., representing a successful design, must primarily be strong enough and sufficiently resistant to withstand the repeated strain of the forces acting upon it. The elastic deformations of all or any of its composite members when stressed to their greatest loads must remain within the confines of safety—i. e.: within the elastic limit of the materials of which they are constructed. The choice of the proper allowable factor of safety, in each and every case, is an extremely important and vital question for the engineer to decide. The rule of the thumb will not do when it comes to the proper dimensioning of an engine or bridge, and the calculations for the correct proportions, dimensions and the proper and economic distribution of the different materials that compose the various parts of his structure must be based upon established scientific and practical facts. Experience, science, and theory must be the guiding factors in the effective elaboration of all his engineering work, each reinforcing the other.

The safe allowable working stress in one specific case may be one-half to one-fourth of the ultimate strength of the material, and yet in another instance conditions may be such that twenty to forty would not represent an excessive value for the safety factor. Then again there are times when the allowable working stresses may not be of such a significant moment as the allowable working strains, which then should form the basis in the calculations for the deter-

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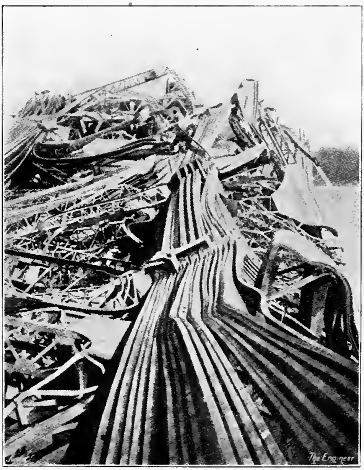
mination of dimensions and selection of proper materials.

We frequently meet conditions where the cross-sectional area of a certain member of a structure can be kept at a low figure, when the working stress only is kept in view, but when we consider the corresponding strain induced by this stress, we may find that the deformation of this single element in the mechanism or structure may have such an influence, in its relationship to immediate adjoining members, that it may not only nullify its own function, but that of the entire design.



From an illustration in the (London) Engineer.

View of Wreckage of Quebec Bridge.

To illustrate the responsibility of the engineering profession and to emphasize this fact to the young graduate about to enter the field of practical endeavor, let it suffice to point to such examples as the collapse of the Quebec bridge over the St. Lawrence and numerous boiler explosions.

An instance that came to the writer's personal notice some time ago where he was called upon to render expert testimony regarding the probable cause of the explosion of a steel tank that had been designed for the storage of compressed air under pressure of several hundred pounds per

square inch, may serve to illustrate the importance of the proper regard for correct calculations in the strength of the design, and for the choice of the right materials. The failure of the tank could be directly attributed to the weakness of a cast iron flange, which, instead of measuring 2½″ to 3″ in thickness, was erroneously considered heavy enough with 1½″ of metal. The cost of this blunder on the part of the designing engineer was the serious injury of several workmen engaged in testing the tank.

There is a growing tendency among many engineers of today to base the factor of safety upon the actual elastic limit and not upon the ultimate strength of the material. In many cases it is really incorrect, in the writer's estimation, where it is necessary to deal with alternating stresses at frequent and rapid applications, to base the factor of safety upon the ultimate strength, because it is an established fact that when stresses exceed the elastic limit of any material it only requires a definite number of these applications until the actual failure is reached.

IT IS THEREFORE NOT ONLY MISLEADING, BUT ERRONEOUS TO USE THE ULTIMATE STRENGTH AS THE BASIS FOR THE FACTOR OF SAFETY. THE TRUE FACTOR SHOULD REPRESENT THE RATIO OF THE WORKING STRESS TO THE ELASTIC LIMIT OF THE MATERIAL IN SERVICE.

PNEUMATIC ASH HANDLING SYSTEMS.

BY R. B. HARRIS, M. E.*

It has happened that several minds working under similar conditions and with like surroundings, but with entirely different objects in view, have almost simultaneously reached the same conclusion. Such a situation seems well illustrated in the development of vacuum cleaning apparatus so commonly known and quite universally applied during the period in which the same principle was being perfected for the handling of ashes. The success of vacuum cleaning by applying air suction with provision for free flow of air to carry dust was paralleled by the success of conveying ashes in similar manner.

The difference, however, in the actual design of the apparatus for two so widely different substances, both to be handled by air, required ingenuity along different lines. In vacuum cleaning the dirt and dust to be carried is relatively insignificant in weight or volume and the necessity of making the apparatus light and portable is pre-eminent, while wear of its parts, in conveying such material, is inappreciable. On the other hand, in handling ashes, the weight and volume to be carried is the first consideration, and the wear and tear while conveying such material demands design of parts of unusually heavy construction.

It at once appears necessary to make the apparatus for handling ashes so heavy that possibility of portable form is out of consideration and such apparatus, therefore, becomes stationary. Ashes also are ordinarily produced under conditions of fixed or stationary character, and the systems, therefore, may readily be designed to serve as collectors of ashes from various points to one place of final accumulation and disposition. This makes the design of pneumatic ash handling machinery to be adapted to fixed—but different—conditions in every plant an engineering problem, and not merely a piping layout.

The GECO Pneumatic Ash Handling System, as exclusively manufactured by the Green Engineering Company, is typical of the development of applying air for conveying purposes. In these Systems a conveyor pipe is located convenient to ash pits, where ashes from furnaces are deposited. In this pipe, ash intakes are provided, into which ashes may be conveniently

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*Class of 1902. Superintendent of Construction, Green Engineering Company, Chicago.

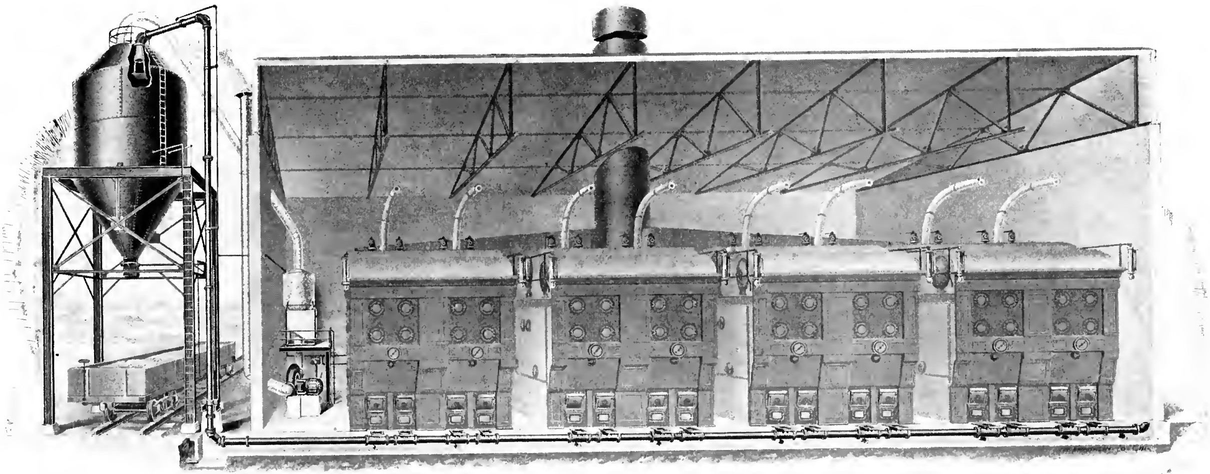
raked or shoveled. A continuous air suction with high velocity air current entering ash intakes is maintained, and the ashes are thereby readily fed into such openings. The conveyor pipe is continued to a separator and accumulating ash tank, in which the high velocity of the air current, bearing the ashes in suspension, is suddenly reduced to almost no velocity by expansion and the ashes at once deposited in the tank. To further facilitate such deposit, the ashes are subjected to a water-spray just before entering the tank, the water serving to wet the ash particles, increasing their weight, as well as to attach the dust of suspension to the larger ash. At an angle radically opposed to the angle of entry of ashes, an exhaust pipe serves to withdraw the air entering the tank by way of its connection to a powerful exhauster; in fact, the exhauster produces the air current through the entire system and its suction on the tank is sufficient to produce the high velocity in the conveyor pipe connected thereto.

Between the tank and the exhauster a dust collector is placed through which the air, separated from ashes, must pass in a somewhat helicoidal path. More particularly, the arrangement provides for imminent contact of air current with water surfaces for the purpose of still further extracting any particles of dust which may not have been deposited in the ash tank.

The exhausters for Pneumatic Ash Handling Systems vary widely in capacity and pressure, depending upon the amount of ashes to be handled, and length of conveyor pipe through which the requisite air must be drawn. The exhausters are driven by either engines, turbines or motors, depending upon the most convenient motive power available in the plant to be served.

The Systems are built in various sizes, rated by the amount of ashes to be conveyed per minute. Thus, for example, a 6″ System has a capacity of 150 pounds per minute; an 8″ System, 300 pounds; and a 10″ System, 500 pounds. Such rates of conveying ashes are, relatively speaking, enormously greater than possible capacities of any other form of ash conveying apparatus. In fact, conveying capacity of Pneumatic Ash Handling Systems exceeds the ordinary ability of one man shoveling ashes under usual circumstances. It is therefore necessary to arrange the intakes convenient to the pits where the ashes accumulate, in order that the possible rate of handling ashes into intakes may be such as to permit one man to feed the full capacity of the System.

It is to be borne in mind that but one ash intake should be open at any one time, and that at this point only can ashes



Pneumatic Ash Handling System for Railroad Car Discharge.

be fed to conveyor pipe. This condition is made apparent by considering two ash intakes open at the same time; the one farthest removed will be without air suction, as suction will naturally be spent at the opening nearest the separator tank. To more readily insure free air supply to the System at all times, the farthest extension of conveyor pipe is left open by attachment of a fitting known as an "Air Intake." This does not interfere with the full suction at any other opening nearer the tank, and at the same time permits free operation of exhauster set during the interval while operative is passing from pit to pit and all ash intakes are closed.

The necessity of restricting the ash intakes to but one opening at any one time is really a decided advantage, from the standpoint of labor required, as the relatively enormous carrying capacity of these Systems makes it readily possible to handle as high as fifteen tons of ashes per hour with one operator, and there are few power plants in which the ash accumulation cannot be handled by one man in ten working hours. It is customary to arrange the size of ash pits sufficiently large that the ash cleaning periods are limited to the work of one man. On account of the convenience, and as the labor involved is not objectionable, ashes are usually cleaned from the pits successively in very short time, and often by the same man firing the furnaces.

The nature of ash from coal differs widely. It may not be generally known that ashes from different coals may vary in weight from as low as 30 to as high as 60 pounds per cubic foot. Inasmuch as the weight of ash to be handled by air influences the amount of air required to float the ashes in the air current, it is apparent that for ash of varying weight different air currents, or air velocities, or really air density must be provided. In this respect, the Systems require other calculations for heavy ash than for light ash. Further, the air current actually established throughout the System is dependent upon the suction maintained at the opening farthest away from the separator tank. As the suction to be maintained in any pipe line with air current moving there through is dependent upon the friction of the air current through the pipe, the length of conveyor pipe, as well as the number and nature of obstructions (such as bends or turns) causing additional friction loss, will enter the calculation of air suction to be furnished by the exhauster set. Thus, the weight of ashes to be handled will determine the relative volume of air to be exhausted, and the friction loss through the System will determine the amount of suction required.

The power consumption of engine, turbine, or motor, driv-

ing the exhauster will then depend upon the volume and suction produced by the exhauster as illustrated above. In some 6″ Systems 15 H. P. is sufficient, whereas the same size System may require 60 H. P., if the latter should employ an extremely long conveyor pipe, with probably several elbows or bends. Similarly, either of these Systems of the same size conveyor pipe may require 15 to 40 more H. P., if intended to handle heavier ash. Corresponding figures for 8″ Systems may involve from 30 to 100 H. P., and 10″ Systems from 50 to 150 H. P.

As the necessary air currents for floating or carrying the ash in suspension are relatively of high velocity, the effects of turns in the conveyor pipe at once become of considerable consequence. The ash entering the System immediately travels toward the center of the pipe where the greatest air velocity is maintained, on account of the least retardation by skin friction of the conveyor pipe. In other words, the ash really does not touch the pipe after entering the air current and while continuing at its maximum velocity. That such is the case is readily understood by considering the ash particles as having relatively large surface on which the air may impinge, and therefore at all times ash particles are affected most by the air current of greatest velocity.

However, when such ash laden air current reaches a bend in the conveyor pipe the heavier ash particles are projected forward to the outer surface or back of such bend, and at their high velocity ashes at once attack this surface in the same manner as a sand blast would attack any surface towards which it is directed. In these Systems suitable provisions are made for replacement of such backs and to conveniently and cheaply repair such abrasions of the fittings occurring at each bend in the conveyor pipe. These fittings may readily be opened by removing hand-holes on the inside curvature, giving access to the back. The life of wearing backs is dependent on the velocity required in the System, on the nature of the ash, and the amount of ashes handled, and may vary from ten days' life to two years', depending upon such conditions. In any event, the cost of replacing and maintaining such wearing backs is insignificant when compared with the savings possible with these Systems over any other method of handling ashes and maintenance of apparatus therefor.

Inasmuch as the disturbance at elbows may, under some conditions, be continued by one or more rebounds of ash from wearing-back to pipe immediately beyond the fitting, it is customary to provide short lengths of pipe directly beyond such fitting for convenient turning of pipe and eventual replacement.

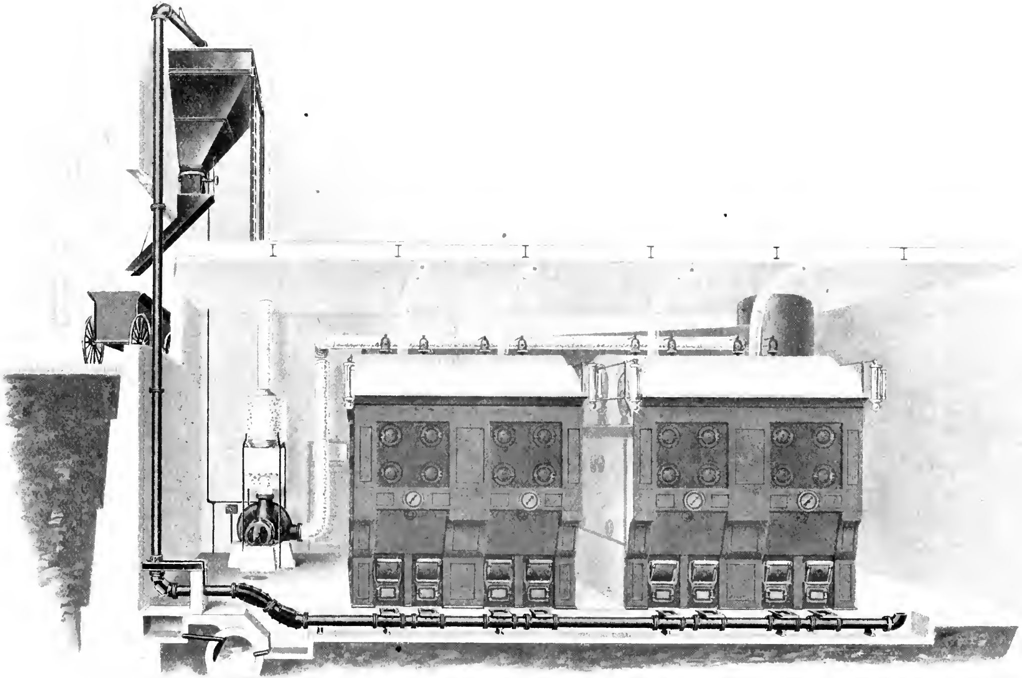
Inasmuch as the conveying capacity of these Systems de-

pends on the velocity established, and the velocities attained depend on the suction provided, it is apparent that air-tight apparatus, fittings, and connections should be provided and maintained throughout, as any leakage between an ash intake opening and the separator tank will at once decrease the suction and thereby the velocity of air current, and also decrease the suspending property of the air in motion at point where ashes are introduced and elsewhere within the System. Should decreased velocity result for some reason, viz., should ashes be fed at excessive rates (which rates then would be beyond the suspending capacity of the air current), a tendency for ashes to lag would result; that is, the effect of gravity would exceed the effect of velocity contributed by the air current, and then the ashes tend to, and would, eventually, lodge in the bottom of the conveyor pipe. Establishing the proper air currents for such excessive feeding, or decrease in the rate of feeding the ashes, would again restore the velocity needed and such particles would be picked up and assume the necessary velocity, passing on as originally designed.

Wet ashes, having much greater weight per unit of volume, would enter the System under the same circumstances as ashes heavier than those capable of suspension by the air current provided in the System. Therefore, wetting ashes and then introducing them into the System usually deposits them in the pipes, and, as wet ashes will stick to any surface even after dried, the introduction of wet ashes is impractical. However, as ashes may be fed hot, or even on fire, into the System, and as all ashes are quenched by the spray before entering the tank, there is really no occasion for wetting prior to feeding into the System. Further, as ashes do not require reshoveling or rehandling, causing the stirring of dust, and as dust from first handling is at once drawn into the System, there is really no desire on the part of operators to expend the additional labor of wetting ashes down.

The operation of these Systems depends only on an engine or motor and its exhauster as the entire moving machinery. These are both conveniently located and away from the ashes to be handled, and may be housed to protect them from the machinery deteriorating conditions usually existing in boiler rooms, or incident to the handling of ashes. The simplicity of the moving machinery of these Systems, and particularly its remoteness from the point where ashes are accumulated, greatly reduces the maintenance cost thereof, and always readily permits its inspection under most favorable surroundings.

As the ashes are drawn into the System, any dust occasioned is at once drawn away, and no opportunity exists



Pneumatic Ash Handling System for Wagon Discharge.

for gases, steam or dust to arise and contaminate the surroundings. The work of the operator, therefore, is relatively pleasant as compared to usual methods of handling ashes. Under these conditions, conspicuously clean boiler rooms and surroundings are some of the attractive features contributed by the System.

The absence of moving machinery in boiler rooms and ash pits has made this System most desirable when compared to ash conveying devices of any other type. No possible danger can confront the operator while feeding ashes into the conveyor, nor is it necessary to risk life or limb in lubricating any moving parts, so common in other systems usually involving parts located in dark or inaccessible places. As ashes are finally stored in sealed tanks, danger from fire is eliminated.

In the description of the System I have mentioned the provisions for angles or bends in the conveyor pipe. These possibilities adapt the System to almost any construction of boiler rooms, as the conveyor pipe line can be arranged to avoid conflict with other apparatus and either pass around, above, or below, where no other system is possible. The ash storage tank may be located either inside or outside of the building, wherever most convenient to final discharge by gravity to either car or carts. Suitable valve for this purpose is attached to the cone-shaped bottom of the separator tanks.

The final discharge from the exhauster set is ordinarily conducted into the chimney or breeching serving the furnaces or, directly into the atmosphere.

The piping connections to water-spray are usually located convenient to controller operating motor, or to the engine throttle, as the starting of the entire apparatus involves only the turning on of the engine, or motor, and opening the water-spray.

The sizes of ash storage tanks vary, depending on disposal arrangements peculiar to any particular plant. Tanks of five tons capacity would be considered small, while 75 tons capacity for railroad car discharge would not be unusual.

The GECO Pneumatic Ash Handling Systems above described are manufactured and installed exclusively by the Green Engineering Company, Chicago, who employ a staff of engineers for the calculations and design of this apparatus. It is not inopportune to mention that several A. I. T. boys are among these engineers.

STRESSES IN AEROPLANES DURING QUICK TURNS.

BY M. B. WELLS.*

The evolutions performed by aviators include, among the most daring, the spiral glides and quick turns. In making a spiral glide the aviator rises to a height of probably several thousand feet and descends in a spiral path either with the motor running or with the power shut off. The speed attained is sometimes very great, the time of making one circuit is short, and the banking of the machine is at a steep angle. No definite data is obtainable in regard to the speed or the time of a circuit in these glides, but in quick turns made in ordinary exhibition flights, time as short as five and one-fifth seconds has been reported. A speed of fifty miles per hour is not unusual in ordinary straight flights, and this speed is doubtless often exceeded in the downward circular flights.

The following is a discussion of the principal stresses existing in a biplane making a complete circuit in five seconds at the assumed speed of fifty miles per hour: The circumference of the circle swept by the machine will be $\frac{5280 \times 50}{60 \times 60} \times 5$ $= 367$ feet, and the radius of the circle will be $\frac{367}{3.14 \times 2}$ $= 58$ feet.

From mechanics we have the centrifugal force of a body of mass M

$$= M \frac{4\pi^2 a}{T^2}$$

where a is the radius of the circle in feet and T the time in seconds during which the mass moves around the circle. The total weight of the machine and operator is about 1,200 pounds. Substituting the known quantities in the above formula and solving for the centrifugal force it is found to be

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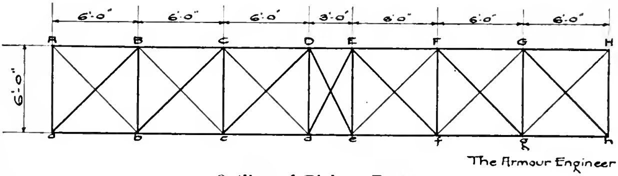
$$\frac{1200 \times 4 \times 3.14 \times 3.14 \times 58}{32.2 \times 5 \times 5} = 3420 \text{ pounds.}$$

This acts horizontally and outward, while the weight of the machine acts vertically downward. The resultant of the two is

$$[\,(3420)^2 + (1200)^2\,]^{1/2} = 3624 \text{ pounds.}$$

The cosine of the angle that the line of action of this resultant force makes with the horizontal is 3420/3624 = 0.94, and the angle is 20 degrees.

With the pressure of the air perpendicular to the surfaces, and sufficient to balance the above resultant force, the angle that the machine must make with the horizontal is 90°—20°= 70°. Observations and photographs of machines in circular



Outline of Biplane Truss.

flight indicate that under extreme conditions they approach such an angle.

The total downward and outward resultant force being 3624 pounds, each pound of weight of the machine exerts a force of 3624/1200=3.02 pounds along lines parallel to this resultant; that is, perpendicular to the chords of the main trusses of the machine.

The accompanying sketch is an outline of one of the two main trusses of a machine, the plane of the truss being perpendicular to the line of flight. For convenience it is placed with its longer dimension horizontal. It is assumed that one-half the weight of the machine is distributed over this truss as follows: At each of the points A and a, 7½ pounds; at each of the points B, b, C, c, and D, 15 pounds; and at d 210 pounds. The right half is loaded the same. Multiplying each of these weights by the constant 3.02 gives the pressure exerted at the respective points, the truss being now turned so that these

pressures are vertical. They are as follows: At each of the points A and a, $7.5 \times 3.02 = 22.65$ pounds; at each of the points B, b, C, c and D, $15 \times 3.02 = 45.3$ pounds; and at d, $210 \times 3.02 = 634.2$ pounds. The total downward pressure on this truss is then, $(634.2 + 5 \times 45.3 + 2 \times 22.65) \times 2 = 1812$ pounds, and this is balanced by the pressure of the air in the opposite direction.

The surfaces are 5½ feet wide, and the total area supporting this truss and its load is $5.5 \times 2 \times 39 / 2 = 214.5$ square feet. The pressure per square foot on the surfaces is $1812/214.5 = 8.45$ pounds. The number of square feet at A is $(5.5/2) \times 3 = 8.25$, and the number of pounds of upward pressure is $8.25 \times 8.45 = 69.7$. The upward pressure at a is the same; the upward pressure at each of the points B, b, C, and c is two times the above or $69.7 \times 2 = 139.4$ pounds; and the upward pressure at D, also at d, is $(5.5/2) \times (3 + 1.5) \times 8.45 = 104.5$ pounds; the corresponding upward pressures on the right half being the same.

The differences between the upward and downward pressures at the respective panel points of the truss give the resultant loads at these points which are to be used in determining the stresses in the truss members. At A the resultant load is $69.7 - 22.65 = 47.05$ pounds upward, and at a it is the same. At B, b, C, and c the resultant is $139.4 - 45.3 = 94.1$ pounds upward, at D it is $104.5 - 45.3 = 59.2$ pounds upward, and at d it is $634.2 - 104.5 = 529.7$ pounds, downward. The algebraic sum of these upward and downward loads is zero.

All diagonals are designed to take tension only. Passing a section through CD, Cd, and cd, and taking moments at d gives the following equation:

$$94 \times 18 + 188 \times (12 + 6) + CD \times 6 = 0;$$

Solving,

$$CD = -846 \text{ pounds.}$$

This is also the stress in DE and EF. The stress in de is the same but of opposite sign. With the same section and the center of moment at C gives the equation $94 \times 12 + 188 \times 6 - cd \times 6 = 0$, which when solved gives $cd = +376$ pounds. The stress in BC is the same, but with opposite sign. With a section across the panel ab and center of moments at b

the stress in AB $= -\dfrac{94 \times 6}{6} = 94$ pounds. The stress in bc

is $+94$ pounds, and the stress in ab is zero.

The upper portion of the post Dd has a tension equal to the upward resultant at D, or 59 pounds. The portion of the post below the engine connection has a compressive stress of $529 - 59 = 470$ pounds. Passing a section cutting BC, Cc, and cd, the forces on the left are all upward and are equal to $2 \times 47 + 3 \times 94 = 376$ pounds. $376 + Cc = 0$, and $Cc = -376$ pounds. Similarly the stress in the post Bb is -188 pounds, and in the post Aa it is -47 pounds.

The vertical component of the stress in Cd is $(2 \times 47) + (4 \times 94) = +470$ pounds, and this multiplied by the secant of 45 degrees $= +470 \times 1.41 = +663$ pounds. The stress in Bc is $(2 \times 47 + 2 \times 94) \times 1.41 = +398$ pounds, and the stress in Ab is $2 \times 47 \times 1.41 = +133$ pounds. The stress in the diagonals of the panel de is zero.

In these results the plus sign has been used for tension and the minus sign for compression stresses.

The above given stresses will be modified when the planes of the main trusses are not approximately perpendicular to the chords of the curved supporting surface.

FOUNDATION CONSTRUCTION OF PROPOSED COMMERCIAL BUILDING.

BY H. W. CLAUSEN, C. E.*

During the years 1872-1874 a circular, brick-lined water tunnel of 7′ internal diameter was constructed by the city of Chicago from the present old two-mile crib to a point near 22nd Street and Ashland Avenue, where it connects with the old West Pumping Station, now called the 22nd Street Pumping Station. The line of this tunnel runs straight from the two-mile crib to a shaft located at Chicago Avenue and Lincoln Parkway, just outside the present Chicago Avenue Pumping Station, and straight from this shaft to a shaft located just outside the pumping station at 22nd Street and Ashland Avenue. The depth of the tunnel below the surface varies, but it is not less than 60 feet at its highest point. This straight tunnel line was adopted on the principle that the hypothenuse of a triangle is shorter than the sum of the other two sides, and of course on this proposition the cost of the tunnel was reduced. It was also believed justifiable to adopt this plan of crossing under private property, because it was supposed that no foundation would ever be carried to such a depth. This reasoning, which was sound enough at the time, is now incorrect, because foundations for our large buildings are now often carried down to rock, which may be as far as 120 feet below the surface.

During the construction of a pile foundation for a building in another part of the city, it was discovered that a pile had penetrated one of the city's tunnels which luckily happened to be only a connection for equalizing purposes, and it cost the city approximately $120,000 to have the damage repaired. After this occurrence it was made a rule of the Building Department, before issuing a permit, to require the O. K. of the City Engineer on all plans showing a foundation of any consequent depth. In 1904 an application was made for a permit to construct a commercial office building on a pile foundation on the south side of Madison Stret and on the east bank of the Chicago River. Now, when this was referred to the City Engineer it was discovered that the tunnel herein described crossed under the property at a depth of about sixty feet below the surface. The permit was therefore held up pending an understanding between the owner and the city. After con-

*Class of 1904. Assistant Engineer, City Chief Engineer's Office, Chicago.

ferences it was finally agreed between the parties that the city should build a caisson foundation for the building and pay the difference in cost between the pile and caisson foundations, respectively. Since the tunnel in question was the only source of water supply to the southwest side, it was imperative that no damage should result to the tunnel as a consequence of

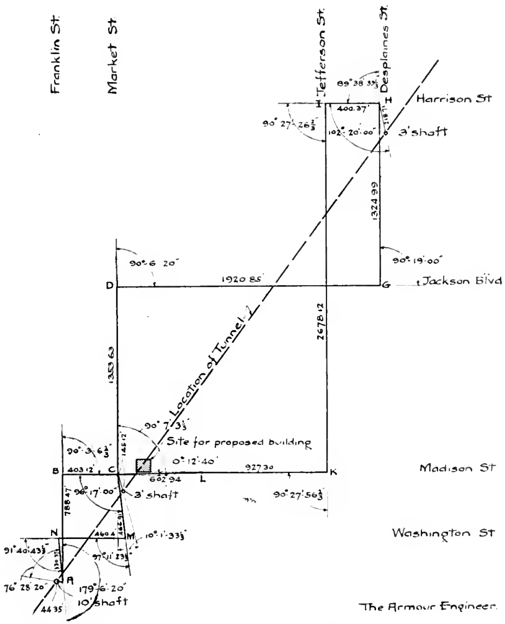


Fig. 1. Plat of Survey.

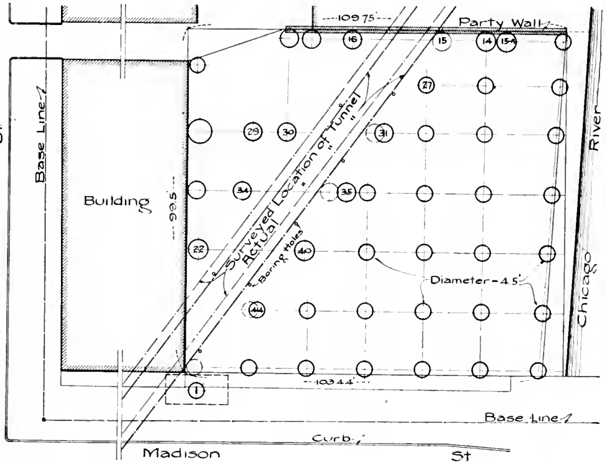
these operations; therefore, the city reserved the right to let the contract directly and supervise the construction of the foundations.

Before the plans could finally be revised to show the location of the concrete caissons it was necessary to know exactly where this tunnel crossed the property. Accordingly a survey had to be made connecting various working and fire shafts along the line of the tunnel. This survey proved

		Feet					N	S	E	W
Course of KL	E	927.30	0°	27′	56⅔″	S	....	7.538	927.270	....
Course of LC	E	602.94	0°	15′	16⅔″	S	....	2.678	602.936	....
Course of MN	E	460.40	1°	9′	40″	W	464.390	....	....	49.037
Course of CM	N	466.91	6°	1′	43⅓″	S	....	9.329	460.305	....
Course of NA	N	330.37	0°	31′	3⅓″	W	330.357	....	....	2.984
Course of AB	S	788.47	0°	22′	36⅔″	W	....	788.453	....	5.187
Course of BC	W	403.12	0°	25′	43⅓″	N	3.015	....	....	403.109
Course of CD	S	1353.63	0°	18′	40″	W	....	1353.610	....	7.350
Course of DG	W	1920.85	0°	25′	0″	N	13.969	....	....	1920.800
Course of GH	S	1324.99	0°	6′	0″	W	....	1324.990	....	2.313
Course of HI	E	400.37	0°	27′	26⅔″	S	....	3.197	400.357	....
Course of IK	N	2678.12	0°	0′	0″	N	2678.120	....	....	....
							3489.851	3489.795	2390.868	2390.780

Courses, Latitudes, and Departures from Base Line IK.

to be rather a difficult one to make because the traffic of the downtown district made progress slow and frequently disturbed the set up of instruments, while the smoky atmosphere made sighting difficult. The survey, as shown in Fig. 1, was finally completed, however, and the latitudes and departures calculated. The error of closure, as may be seen from the accompanying table, was found to be 0.08′, or one inch, east and west; and 0.06′, or three-quarters of an inch, north and south . Under the existing conditions this was considered to



The Armour Engineer.

Fig. 2. Plan of Foundation Caissons for Proposed Commercial Building.

be a good closure, and so the line of the tunnel with reference to the building lot was then figured . The foundation plans were next completed, as shown in Fig. 2—the caissons along the tunnel being planned to clear the outside of the tunnel brick-work by at least three feet. The soil through which the tunnel is built is medium stiff blue clay, and, as the internal hydrostatic pressure in the tunnel was about 20 pounds per square inch, it was considered necessary to make the excavation of the tunnel caissons from a point 8 feet above the top of the tunnel using 20 pounds air pressure. The other caissons were to be excavated by ordinary means, i. e., under atmospheric conditions. The column loads over the tunnel were to be

supported by steel box girders spanning the tunnel and were to be completely surrounded by concrete.

Work was commenced on a number of the common caissons, the tunnel caissons being left for the installation of the air locks. Caisson No. 22, the first tunnel caisson attempted, was excavated by ordinary means to a depth of abouc 8 feet above the top of the tunnel. At this point excavation ceased

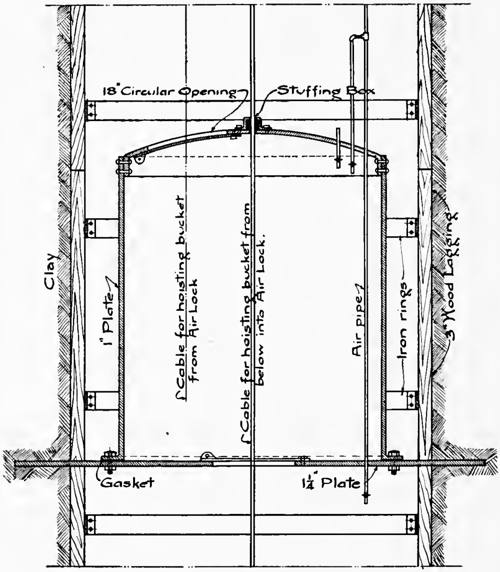


Fig. 3. Vertical Section Through Air Lock.

and an air lock, constructed about as shown in Fig. 3, and located as indicated in Fig. 4, was installed. After the air lock was ready for service work was again resumed and the excavation carried to rock, the caisson then being filled with concrete up to the air lock under air pressure, and finally to the surface, after the removal of the air lock. In order to expedite the work, another air lock was constructed for use in the other tunnel caissons, this lock being different from the

one shown, in that instead of bolting the top hood, as it were, to the lower plate securely bedded into the clay, the lock consisted simply of plates similar to the lower plate of the one shown, with the space between the plates being lined with the usual wooden lagging of the caisson. This latter air lock was installed at about the same depth in Caisson No. 15 on the opposite side of the tunnel. When the excavation under air

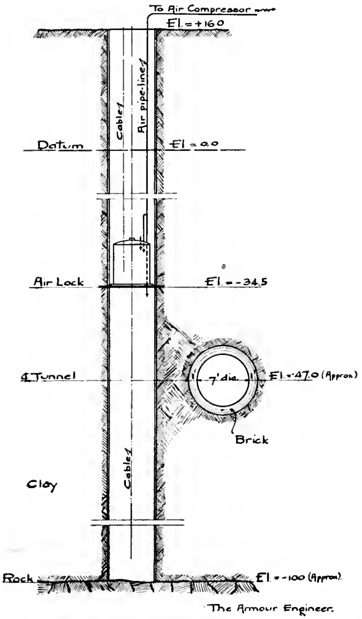


Fig. 4. Typical Construction (with Air Pressure) of Caisson Near Tunnel.

pressure in this caisson had proceeded to an elevation corresponding to the springing line of the tunnel, the well digger exposed the brick-work of the tunnel at the southeast edge of the caisson and the water slowly began to come in. He immediately came up, and the well, or caisson, was allowed to fill up with water. After an investigation, during which boring holes were sunk to locate the tunnel, it was found that the tunnel was located 3 feet northwest of the supposed or

surveyed location, and that the caisson in question had exactly struck the tunnel tangentially.

It may here be stated that the clay soil, through which the caissons were excavated, was full of sand seams and sand pockets so that often the air pressure would suddenly drop from 20 pounds to 5 pounds, this creating consternation among the engineers in charge. This unfavorable circumstance, coupled with the slow and cumbersome method of progress, made the excavation under air pressure anything but popular. The plans were accordingly modified so that the caissons on the northwest side of the tunnel were moved over 3 feet, this necessitating much heavier and longer box girders for spanning the tunnel. Due to the fact that the caissons on the southeast side of the tunnel would now be 6 feet instead of 3 feet away from the tunnel, it was decided to sink these caissons by ordinary means, except that in passing the tunnel only one-half of a section (or 2½ feet) should be excavated before being "lagged up," the usual section being 5 feet deep. This method was successfully employed on all the caissons on the southeast side of the tunnel.

It may be of interest to digress for a moment from the subject in hand and relate an experience in one of these caissons which for a while gave the writer no small scare. It was about 1 a. m.—the writer being stationed on the work for twenty-four hours or more at times when any one caisson was being excavated past the tunnel, and the excavation in Caisson No. 30 was down to a point about opposite the top of the tunnel. It had taken the well diggers a whole shift of 8 hours to set in place the last set of lagging and steel rings, due to the extreme swelling of the clay, and of course this caused a good deal of apprehension on account of the proximity of the tunnel. Now, when the new shift of well diggers had excavated about a foot below the lagging, a stream of water suddenly broke through the clay with great force, striking one of the diggers in the face. The men were quickly hoisted up away from danger, for it was supposed that the water from the tunnel had broken into the caisson. By means of a float attached to a steel tape, the writer discovered that the influx of water diminished instead of increased, finally ceasing when there was about 10 feet of water in the caisson; this proved of course that the water had not come from the tunnel. After an investigation it was found to have come from Caisson No. 29, which was only 4 feet east and which had been excavated and concreted up

some two or three months previous. The top of the concrete in this caisson was about 14 feet below the surface, and, being a low point, rain water had accumulated in it to a depth of about 10 feet. When Caisson No. 30 had reached the depth stated, the hydrostatic pressure from this water was sufficient to break through four feet of clay and drain the water from the higher to the lower level.

For the caissons on the northwest side of the tunnel it was decided to excavate in $2\frac{1}{2}$ foot sections as before, but to employ a steel shield about 3 feet long with a cutting edge, thus leaving no exposed excavation at all. The cutting edge was jacked down $2\frac{1}{2}$ feet when a set of lagging and steel rings would be inserted inside of it before proceeding with the next section. This method was carried out in Caisson No. 35 but was found to be so slow and cumbersome that it was abandoned in favor of the others. It happened in Caisson No. 35 after hard pan had been reached, and the full depth of the caisson excavated, that while it was being belled out to give greater bearing area, water broke in from the tunnel and filled it, thus making it necessary to concrete it under water. This leak was attributed to the clay drying up and cracking as a result of the long exposure to the air, this long exposure being necessary when using the shield. The shield was therefore discarded and the work satisfactorily completed, except in Caisson No. 1, by means of $2\frac{1}{2}$ foot sections as used on the southeast side of the tunnel. In Caisson No. 1 water came in, as in Caisson No. 35, while the belling-out was in progress. Due to this technical violation of the contract, the owner refused to accept the foundation as built, so the city was compelled to purchase the lot, which it still owns and uses as a storage yard for the Bridge Department. Caisson No. 15, where the tunnel was actually struck, was filled up for 8 feet with sand and cement, in bags, and then with clay to the surface.

This unfortunate circumstance cost the city a good deal of money and so it was decided that it would be economy to build under the streets belonging to the city another tunnel, this to replace this old cross-town tunnel, and thus avoid any further difficulties with foundation construction. This was accordingly done and the Blue Island Avenue tunnel now has replaced it.

It was the good fortune of the writer, about a year ago, to have the opportunity of walking through this old cross-town tunnel from Van Buren and Jefferson Streets to Chicago Avenue and Lincoln Parkway. An examination showed no

cracks and no traces whatsoever of any damage done to the tunnel at the point where it was encountered in Caisson No. 15 several years before. This inspection also revealed the fact that the fire shaft at Market and Madison Streets was off the center line of the tunnel by about 2½ feet to the southeast, which accounted for the error in tunnel alignment as obtained from the survey. It seemed a pity to be compelled to abandon this old tunnel, because the examination showed a perfect piece of work in an excellent state of preservation after 40 years continuous service. The line and grade of the tunnel was also perfect, and the depreciation from any cause whatsoever, except in the top of the working shafts, was, I should say, nothing.

It is now the intention of the city to use the property purchased and herein discussed as the site for a large central police station and fire engine house.

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EDITORIAL.

Realizing that in the past much has been said and written in an effort to bring to the attention of both our student and alumni bodies the aims and expectations of THE ARMOUR ENGINEER, we hardly believe that any further discussion or information regarding the scope of this publication will be particularly interesting to our readers at this time. However, we now wish to express to our contributors our appreciation of their painstaking efforts in the preparation of these articles, for we feel that their substantial support will go far toward increasing the general interest in our magazine. Also, for the benefit of those who still expect that a special solicitation is necessary, we want to repeat the now standing invitation to all Armour men for contributions to our columns on any of the engineering topics in which they are particularly interested.

In the article appearing in this issue on "Briquetted Coal and Its Value As a Railroad Fuel," Mr. Malcolmson discusses a subject which we believe will prove of exceptional interest to our readers, it being so closely allied to the present and familiar subject of conservation and development of our national resources. A very instructive account of the coal briquetting industry from its earliest days is given, together with present conditions in its development; the article concluding with a summary of the many advantages of briquetted over raw coal.

The electric-resistance furnace, which several years ago gave the graphite industry such an impetus, is now rapidly being extended in its application to the numerous industries in which exceedingly high temperatures are required, and we have from Mr. Badger one of the first of a number of articles on the various forms of these furnaces, together with an account of their applications to the heating of different metals and other refractory substances.

The many advantages of the electric-motor over the steam-engine operation of rolling mills are carefully brought out in the article appearing in these pages on "The Electric Driving of Rolling Mills." In this discussion is also contained an answer to the question so frequently asked by those not very familiar with electrical power transmission, as to the advantages of alternating current in the transmission of large amounts of energy over long distances. Another item of particular interest is the strong argument in favor of steam turbines over the gas engines as the prime movers for the generators, although at first glance it would seem that the direct conversion of blast furnace gas into mechanical and then into electrical energy would be more economical if the intermediate generation of steam were not involved. However, a careful consideration of the points brought out in Mr. Dean's article will show that, everything considered, the steam turbine has a great many "talking points."

The Pneumatic Ash Handling System as discussed in this issue by Mr. Harris offers a very simple, economical, and comparatively new solution to the problem of ash handling in present day boiler rooms.

Owing to the rather recent development of this system, the calculations entering into the various designs have not been gone into until they shall have been confirmed by data from actual tests; so the author has written principally on the general features encountered in design and installation of these systems.

With the extremely rapid application of water power to the production of electrical energy, there has grown up in recent years a new field of engineering activity in which the demand for trained and experienced men is far greater than the supply. Realizing this, and the need of giving to the technical student desirous of fitting himself for work in this sphere of engineering a course of thorough instruction in the fundamentals, as well as in many of the details in the successful design and construction of hydro-electric plants, there is now being offered at A. I. T. a course in hydro-electric engineering. As this name indicates, and as a glance at the subjects taught confirms, no really new course has been created—simply a combination of subjects from the hydraulic and electrical courses effected.

It is doubtful if many of the hydro-electric engineers of today ever had the opportunity of pursuing courses of study containing a combination of these two branches, for the reason that up to within a comparatively few years very distinct lines have separated the hydraulic and electrical branches. Now however, we see in the hydro-electric course where much has been done toward closing the gap existing between the two separate courses just mentioned, and in view of this fact believe that graduates now entering this field of work are equipped with a foundation which will soon enable them to hold their own in matters of design and construction.

That a course in hydro-electric engineering should be established in all large technical schools is evidenced by the prejudice and suspicious attitude shown toward many of the proposed hydro-electric developments of the present day; and the reason for this existing suspicious attitude may be attributed largely to the results of unintelligent engineering and management on the part of men who really are not qualified by their previous training and experience to be put in charge of work requiring such a broad training. While there are comparatively few instances of absolute failures which can be laid directly to the miscalculations of the engineers in charge, yet there are many instances of where insufficient preliminary investigations and calculations have permanently reduced the efficiency of what might otherwise have been very successful power developments.

The necessity of a broad insight into the many phases of a successful development of our water power resources has been mentioned, and in an attempt to show this we might add that it is just as essential for an engineer connected with hydro-electric work to have a knowledge of the legal, financial, and commercial aspects of the problem, as it is of the engineering features. In fact many of the problems of design and construction admit of much easier solutions than do those in financial and commercial matters, and the ability to grasp them will often settle in a week what might otherwise take the strictly technical man years of investigation to determine in regard to the feasibility of a given project.

This, then, would also seem to present a good argument in favor of even more instruction than is now given the technical student along the lines of work not usually supposed to enter into the work of the engineer and yet so often connected with it; and doubtless when engineers become more familiar with those subjects outside of their own sphere much will have been done toward giving to the engineering profession the rank among other professions to which its achievements show it is entitled.

CIVIL ENGINEERING SOCIETY.

The Civil Engineering Society is today the most prosperous of the several engineering societies here at school, this being due in part to the interest taken by the upper classmen of the Department of Civil Engineering, and, in part, to the co-operation of the department's faculty, all of whom are members—Prof. Phillips, Associate-Prof. Wells and Assistant Prof. Armstrong, as honorary members, and Messrs. Dean and Penn as Senior members. The active membership of the society at the present time is about fifty.

The first meeting of the year was held on Tuesday, October 25, 1910 in the Engineering Rooms, Chapin Hall, the speaker of the evening being Dean L. C. Monin, whose subject was "Standards of Professional Conduct." Dean Monin especially emphasized that an engineer has duties to four parties—(1) his client, (2) himself, (3) his fellow engineers, and (4) the public. The several codes of professional ethics now adopted by several of the older professions were mentioned, and the hope expressed that the engineering profession soon adopt such a code. The necessity of membership in engineering societies was discussed. Dean Monin emphasizing the fact that the engineering student should start by joining the society here at school of whatever branch of engineering he was particularly interested.

On the evening of November 8, 1910, the Society was addressed by Mr. Henry W. Clausen. Class of '04. Assistant Engineer in charge of pumping stations and tunnels for the city of Chicago. Mr. Clausen gave some "Hints to Young Engineers," and in his talk, as well as later by answering questions put to him. made his audience acquainted with many practical suggestions and short cuts on the job, especially as relating to street, tunnel. and road improvement work.

"Irrigation in the West" was the broad title of Mr. Frank A. Coy's talk on Tuesday evening, November 22, 1910. Mr. Coy, also an Armour graduate of the Class of 1904. has recently been engaged in work on several irrigation projects in several of the western states. The reasons for these projects, preliminary proceedings necessary to get them under way, the methods of design. and actual construction, were all taken up in detail and discussed by Mr. Coy.

The last meeting of the calendar year was held on December 6, 1910, with Mr. George H. Bremner, Engineer of the Illinois District, Chicago, Burlington & Quincy Railroad Com-

pany, as the speaker of the evening. His subject was: "The District Engineer on a Railroad: His Duties and How He Performs Them." Mr. Bremner is well qualified to speak on that topic, and many phases of a District Engineer's work were taken up. Organization and standardization of work were especially emphasized as being essential to success in such a position. Blue-prints of various C. B. & Q. R. R. Co.'s standard constructions in track work, construction plans for their large freight yard at Galesburg, Ill., and plans for several bridge sites, were shown.

A new feature of the work this year is the attempt to interest the alumni of the Department of Civil Engineering in the society and its work by keeping them posted regarding its meetings. Many of them, of course, cannot be reached, but a large number of those who have been communicated with have accepted the invitation to attend the meetings. This is indeed gratifying and it is to be hoped that this interest of the alumni will continue to increase.

O. R. ERICKSON.

MECHANICAL ENGINEERING SOCIETY.

The Armour Institute Student Branch of the American Society of Mechanical Engineers has progressed thus far this year with pronounced success, meetings being held on the first Wednesday of each month. While it is desired to select some talent from the engineering profession at large to lecture at these meetings, the main purpose of the society is to call upon its members for papers and lectures on engineering subjects, in order that they may subdue the reluctant attitude often manifested when called upon to speak, and to acquire the ability to lecture in public without hesitancy.

The "Annual Smoker" of the Society was held in October, and the first lecture given in November by Mr. J. C. Peebles, whose subject was "Simultaneous and Automatic Control of Coal and Air Supply to a Boiler Furnace." At the December meeting Mr. R. B. Ambrose (member) lectured on "Producer Gas and Some of Its Methods of Manufacture." Each meeting was attended by about thirty-five persons, constituting students and members of faculty. The men who lectured gave very interesting discussions, and the society feels grateful to them for their efforts.

On January 4th, 1911, Mr. C. E. Sargent, M. E., of Chicago, delivered an illustrated lecture on "Gas Engines." The

meeting was held in Science Hall, and the anticipation of a large attendance was fully realized. Mr. Sargent easily indicated that he is a pioneer authority on this subject, and for his kindness the society feels very thankful.

The present membership of the society numbers about twenty-five, and any Junior or Senior Mechanical student is eligible to membership. The local society, being affiliated with the American Society of Mechanical Engineers, renders it possible for the members to procure proceedings of the above society and to become members of its student branch.

C. E. BECK.

CHEMICAL ENGINEERING SOCIETY.

Students of the Chemical Engineering Society are very active in the affairs of their society this year and have taken exceptional interest in all the meetings held so far. The objects of this organization are, of course, substantially the same as those of all engineering societies; namely, to create a general atmosphere of sociability among its members, and to become familiar with the application to modern chemical engineering practice of those principles studied in the class room.

The first smoker of the society was held Wednesday, November 9th, with the three upper classes well represented and as many faculty members present as could possibly attend. During the evening Professor Tibbals gave a short talk in place of Professor McCormack, who was unable to be present; the remainder of the evening being spent in the conventional smoker style.

The first regular talk before the society was given by Mr. F. M. De Beers, an Armour graduate of 1905, now president of the Swenson Evaporator Company, on Thursday, December 8th. Mr. De Beers discussed and explained the many factors entering into the design of evaporators for various substances, and clearly showed that this work requires the services of men who, as it were, are a combination of chemist and mechanical engineer, a combination to be looked for in the chemical engineer.

H. SIECK.

ARMOUR BRANCH OF THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

Recognizing the advantages to the student body of meetings for the reading and discussion of professional subjects, the Armour Branch of the A. I. E. E. was organized for the reading and discussion of papers as published in the "Transactions of the American Institute of Electrical Engineers," and for the preparation, presentation and discussion of original papers by members of the organization and other individuals.

The policy pursued so far this year has been to have original papers presented by members of the society, believing that the new members would feel more disposed to take part in the discussion of the subject if presented by a fellow student. The remainder of the school year will be devoted to papers presented by members of the Faculty and practicing engineers, thus giving those of the society who complete their course this year an opportunity of discussing the practical side of engineering work with men of experience.

The Armour Branch held its first meeting of the school year on October 27, 1910, at which Mr. L. L. Williams read a paper on "Car Lighting," in which he pointed out the advantages of electric illumination in cars. Following this came a description of several present day methods of car lighting, after which the advantages of the "head end," the "axle-light" and storage battery systems were discussed. The main part of the paper, however, took up and explained the various parts of the Bliss system, which uses a generator driven from a car axle.

On November 17, 1910, Mr. G. E. Williams read a paper before the society on the "Otis Electric Elevator Control." He discussed the duties and early development of electric elevators, and by means of slides and blue prints illustrated the form and principle of the Otis control. The wiring diagrams were traced, the operation of each explained, and the merits of the safety appliances discussed.

Following the plan of the society, the third meeting, held Dec. 15, 1910, was given up to the discussion of the "Interpoles in Synchronous Converters," as published in the "Transactions of the A. I. E. E." The subject was divided amongst the members and each assigned the preparation of a portion of the paper.

Mr. James H. Jacobson, Engineer Inspector, Board of Supervising Engineers, City of Chicago, addressed the society January 5, 1911, on "Railway Converter Sub-stations." By means of photographs projected on a screen, Mr. Jacobson explained the construction and equipping of sub-stations from the time earth is turned for the foundation until the last machine has been installed.

J. H. FLETCHER.

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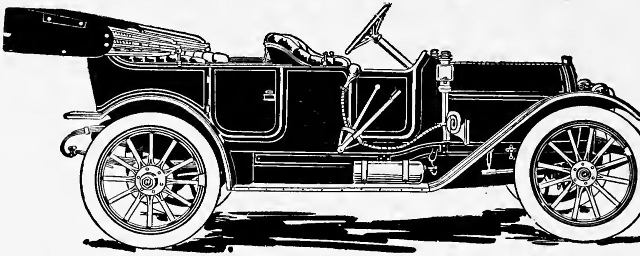

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Prof. Gebhardt's Letter—READ IT

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CHICAGO

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Oct. 19, 1910

Halladay Motor Company,
1421 Michigan Ave., Chicago, Ill.

Gentlemen:—In reply to your favor of the 15th inst. beg to state that the Halladay 1911 "40" chassis recently purchased by us is to be used in our Mechanical Engineering Laboratory for experimental purposes.

A number ot types of machines were examined, but the Halladay 1911 "40" proved to be the best suited for our purpose on account of its simplicity in construction, accessibility for repairs, flexibility for experimental purposes and all-around good workmanship.

The machine is to be equipped with power, transmission, absorption and traction dynamometers, optical power indicator, speed indicating and recording devises, special apparatus for recording the shock-absorbing properties of the tires and springs—in fact, a full complement of special appliances for studying the action of all working parts under various conditions of operations.

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EFFICIENCY TESTS OF SCHENECTADY POWER CO.'S HYDRAULIC TURBINE UNITS NOS. 2 & 3.

By STANLEY DEAN, C. E.*

The Schaghticoke Hydro-Electric Development of the Schenectady Power Co. is located on the Hoosic River at Schaghticoke, N. Y., twelve miles N. E. of Troy, N. Y., and 22 miles east of Schenectady, N. Y. At this point the Hoosic River bends in the form of a letter "S" in a distance of about two miles, measured along the stream, and in this length it has a fall of approximately 150 feet. The stream flow and head are used to develop 20,000 H. P., a small part of which is used locally for lighting and motor service, but the greater part of which is transmitted to Schenectady.

In brief, the development consists of a solid concrete spillway dam built diagonally across the river at the head of a series of falls and rapids, and an intake at the down stream end of the dam leading to a canal 2,300 feet long cut through earth and rock, ending in a forebay from which the water is led by means of a circular steel pipe across a bend in the river to a circular steel surge-tank on the opposite bank.

From the surge-tank four main unit steel penstocks each six feet in diameter and one exciter penstock two feet in diameter, lead to four 5000 H. P. vertical-shaft water-turbines and to two horizontal exciter turbines, respectively, located in the power house, from which the water is discharged into the river below the foot of the last rapids.

Each of the four main units consists of a "Pelton-Francis" inward and downward flow type of reaction turbine, designed for a full load output of 5000 H. P. at 300 R. P. M. under a head of 146 feet, and mounted on a vertical shaft directly beneath its alternator. Each alternator has a full load output of 3000 K. W. at full load at 4400 volts. For transmission to Schenectady this is stepped up to 32000 volts.

It is the purpose of this paper to describe the apparatus and methods used in tests to determine the efficiency of two of the main water turbines.

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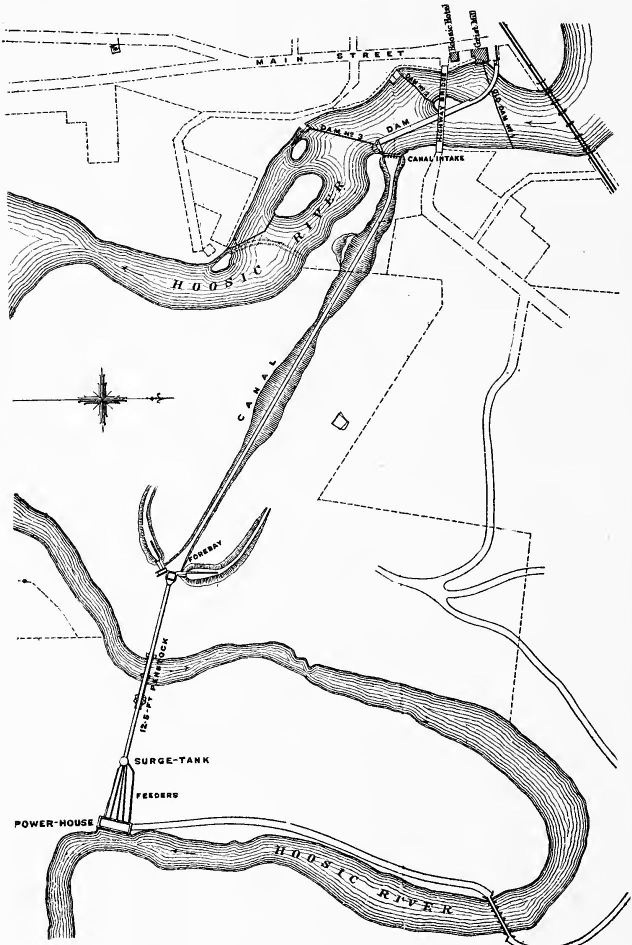


Fig. 1. General Plan of Schaghticoke Plant of the Schenectady Power Co.

Previous to these tests an attempt had been made to measure the water discharged from the wheels, by means of a sharp crested weir built across the race. Owing to the shortness of the tail race however it was found that an accurate result could not be obtained in this manner on account of the eddies from the draft tube causing a varying head over the weir. After various methods had been tried to obtain an adjustment of the water surface to eliminate the sources of error, the conclusion was reached that some other method must be used. At this time an accomodating flood came along and carried off weir and gauges, leaving only the abutments standing, and thus settling that method of testing. It was then decided to install a pitot tube apparatus in the penstock feeding the wheel to be tested, which was accordingly done.

Description of Pitot Tube Apparatus for Measuring the Velocity in the Penstock

If a straight tube be bent at the end to form a right angle and the tip submerged in a flowing stream and so pointed that the mouth of the tip is directly opposed to the current, the water will rise in the upright part of the tube to a height above the water surface which is theoretically equal to $v^2/2g$, the velocity head of the stream. If, now, a pitot tube be inserted in a pipe containing water flowing under pressure, the mouth of the tip being parallel to the axis of the penstock and opposed to the direction of flow, and a straight pipe be inserted in the edge of the penstock so that its mouth is normal to the axis of the penstock and direction of flow, water will rise in the stem of the pitot tube to a height of $h + v^2/2g$ equal to the sum of the pressure and velocity heads in the penstock, while in the stem of the straight tube the water will rise to a height of "h" equal to the pressure head in the penstock. The difference in height of the water columns in the two stems will be equal to $v^2/2g$ and will represent the velocity head in the penstock at the tip of the pitot tube. To measure a head of approximately 150 feet it would be necessary to have a vertical stem 150 feet high, but we may confine the heights within reasonable limits by forcing the water column down, by connecting a source of compressed air to the top of the tube. This was done in the test (see Fig. 2) where the distance A-B equal $v^2/2g$, the velocity head at point of pitot tube.

At a point on the penstock about thirty feet uphill from the elbow at rear of powerhouse, shown on Fig. 5, the pitot tube apparatus was installed to measure the velocity at stated points in the cross section of the penstock. The apparatus

(see Fig. 2 and Fig. 3) consisted of two duplicate pitot tubes, shown in detail in Fig. 6, arranged to slide horizontally and vertically through stuffing boxes screwed into the shell of the penstock, and so graduated that the point of the pitot tube could be set at any desired position on the horizontal and vertical diameters (see Fig. 7) of the penstock. The stem of each pitot tube was of brass and about seven feet

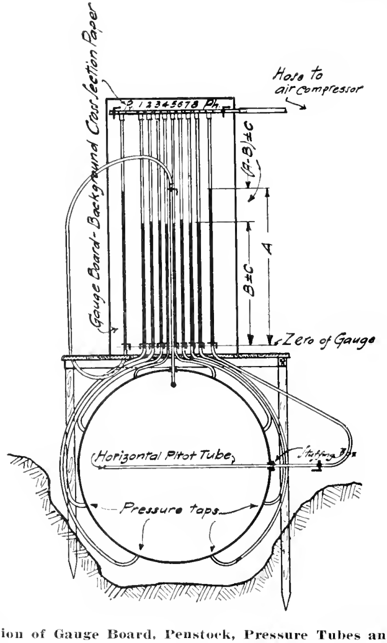


Fig. 2. Elevation of Gauge Board, Penstock, Pressure Tubes and Pitot Tubes.

long. To the end of the stem was securely clamped one end of a flexible hose about twelve feet long, the other end of which was passed over and clamped to the lower end of one of the exterior vertical glass tubes shown on gauge board in Fig. 2, the vertical pitot tube being connected to the glass tube on extreme left and the horizontal pitot tube to the one on extreme right. About one foot uphill from the pitot tube cross-section, eight small iron pipes were tapped in to the

penstock at points equidistant from each other around the circumference, i. e., separated from each other by 45 degree angles, and bent around in easy curves to connect by short lengths of rubber hose to the eight vertical glass tubes on gauge board, numbered 1 to 8 on Fig. 2, between the pitot tube gauge glasses. Each of these eight pressure gauge glasses and two pitot tube glasses were connected by rubber hose and iron "tee" sections of pipe to form a horizontal header at

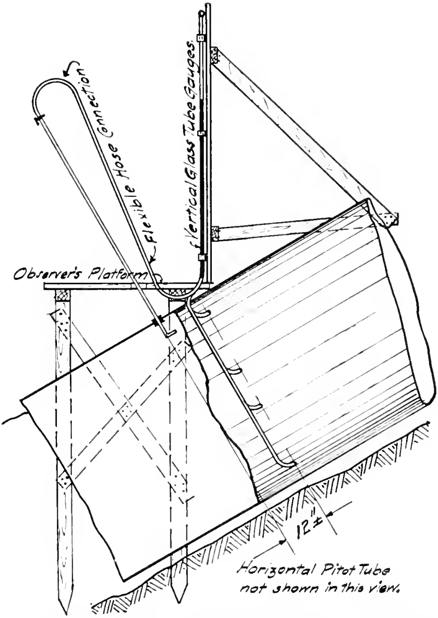


Fig. 3. Section and Elevation of Gauge Board, Penstock, Pressure Tubes and Pitot Tubes.

top of gauge board. One end of this header was connected by rubber pressure hose to the compressed air storage tank located in the power house. At the other end of the header was placed a blowoff cock to let out excess compressed air. Pet cocks were placed at the top of each pitot tube, at the connection of each pressure pipe to penstock, and at the base of each glass gauge tube on the gauge board. One pet cock was also

connected in between the header and compressed air hose to admit or cut off the air pressure. All gauge glasses were securely fastened in position on gauge board by clamps and screws. Immediately behind the gauge glasses and forming the background of the board was pasted a sheet of cross section paper graduated in inches and tenths. The gauge board was mounted on a timber platform and securely braced into position as indicated in Fig. 3. To insure true position of the pitot tubes and to support them, planks were placed parallel to and immediately beneath same. These planks were graduated to correspond to the numbered points shown in Fig. 7. In order to keep the point of pitot tube from being bent downstream by the flow of water in the penstock, 2″x⅜″ iron guides

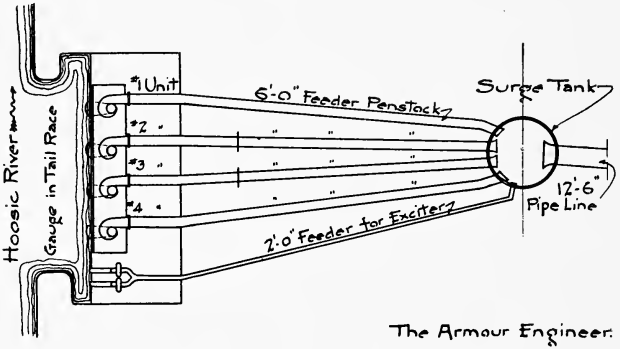


Fig. 4. Plan of Penstocks, Surge Tank and Power House.

at right angles to each other were securely bolted together and to the penstock immediately behind the line of travel of the pitot tubes, to support same. The detail of these cross braces and guides is shown in Fig. 8.

The detail of the tip of pitot tube shown in Fig. 6 is worthy of note. The tip proper was of brass, three inches long, accurately bored, and smoothly finished to the dimensions shown, and was screwed on to the stem of the pitot tube. The mouth of the tip was ¼″, which dimension decreased to 3/32″ at the throat and then enlarged to ¼″ again, the inside diameter of the stem and glass gauge rods. The object of this contraction at the throat was to reduce the surging of the water columns in the glass gauge tubes due to small

changes in the velocity of water in the penstock during the test periods and to render the time of surge the same for both up and down motions, thus enabling the observer to read the gauge with greater accuracy.

Description of Apparatus for Measuring the Effective Pressure Head on the Turbine

As stated in the brief description of the plant at the beginning of this article, the water was led from the impounding reservoir by means of a canal and single conduit to a surge tank in which it was allowed to rise to the level of the hydraulic gradient. From the surge tank the feeder pipes led directly to each unit at the power house. The effective head

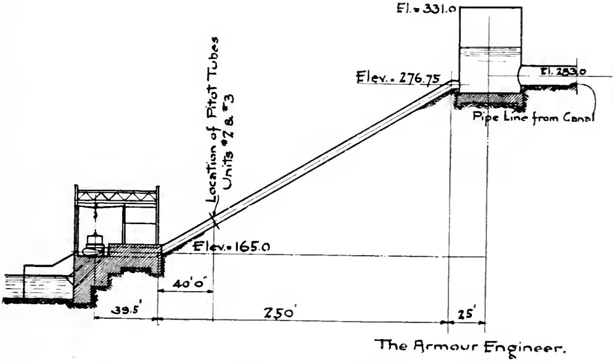


Fig. 5. Vertical Section, showing Penstocks, Surge Tank and Power House.

on the turbines when running was therefore the difference in level between the water surfaces of the surge tank and tail race, minus the loss in head between the surge tank and the entrance to the scroll case, due to entrance loss at connection of feeder penstock to surge tank, and to bends and friction in penstock, plus the velocity head of the water at the entrance to scroll case. In such a case all losses in the scroll case, guides, vanes, and draft tube are considered as the hydraulic losses in the turbine unit itself, and therefore are not to be deducted from the effective head as stated above.

If we measure the actual pressure head at the entrance to the scroll case and add to this the difference in level between the point of measurement and tail race, we have the

total pressure head. Adding to this the velocity head at this point—i. e., at the point of measurement of pressure head. we obtain the total effective head on the turbine. This method was accordingly pursued. In Fig. 9 is shown diagramatically the location and relation of gauges for determining the pressure head on the wheel. At two points in the tail race were located ordinary hook gauges with their zeros set accurately at elevation 150.0. The gauge reading added to 150.00, thus gave the exact water elevation of the tail race above datum.

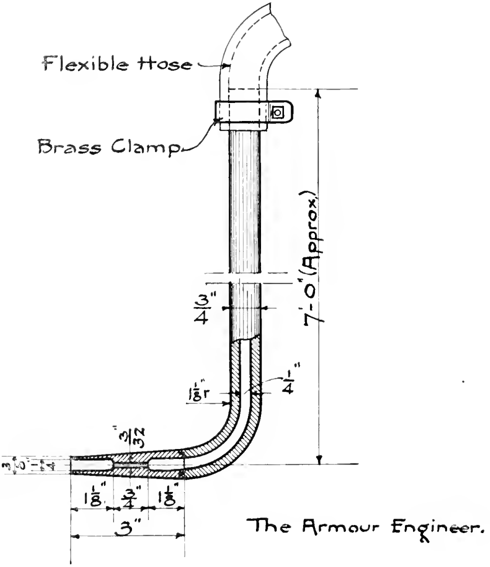


Fig. 6. Detail of Pitot Tube.

To measure the pressure head on the scroll case, a small iron pipe was tapped into same, near the center, and led to a vertical "U" mercury gauge and connected to the upper end of one of the vertical tubes by a rubber hose clamped over same.

Between the upright columns of the gauge a steel tape graduated in feet and tenths, was stretched with its 150.0-foot mark accurately placed at elevation 165.0. A stop cock

shown in Fig. 9 near point of connection of pipe to scroll case controlled the admittance of water under pressure to the gauge tubes. Before opening the stop cock, mercury of specific gravity of 13.54 was poured into the funnel at the top of the gauge, and of course rose to equal heights in the parallel columns. To measure the pressure head, the stop cock was then cautiously opened, the full pressure gradually allowed to depress the right hand column and correspondingly force upward the left hand column. By reference to Fig. 9 it will be seen that the difference between the tops of mercury columns "Z" read on the tape represented the height of a column of mercury that just balanced the transmitted water

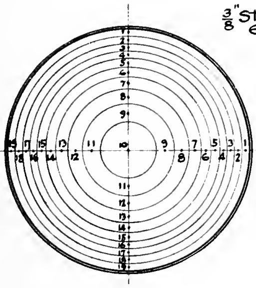


Fig. 7. Cross Section of Penstock, showing Points on Pitot Tube Traverses.

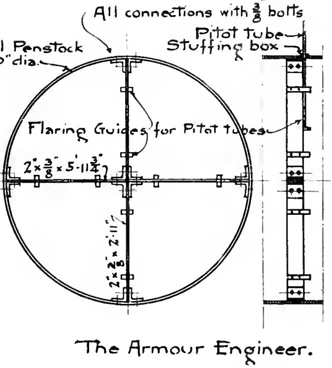


Fig. 8. Details of Cross Braces and Guides for Pitot Tubes.

pressure from the scroll case at the elevation of the top of right hand mercury column. Multiplying this difference of level "Z" by the specific gravity of the mercury (13.54) gave the height of the hydraulic gradient above the top of the right hand mercury column. Add to this height (13.54 Z) the reading "Y" and we have the height of the hydraulic gradient above elevation 165.00. Adding this reading to 165.00 we have the elevation above datum of the hydraulic gradient. Subtracting from this latter elevation the elevation of tail water we thus have the total pressure head on the turbine. From our observations with the pitot tube on the penstock we obtain the mean velocity and quantity of water

flowing through the penstock to the wheel. Then $q = a_1v_1 = a_2v_2$, where q= total quantity of water in cubic feet per second, a_1 = area of penstock at point of velocity measurement, a_2 = area of cross section of scroll case at point of pressure tap, v_1 = mean velocity at same point, v_2 = mean velocity thru scroll case at point of pressure tap. The velocity head at this point equals $v^2/2g$, which, added to the total pres-

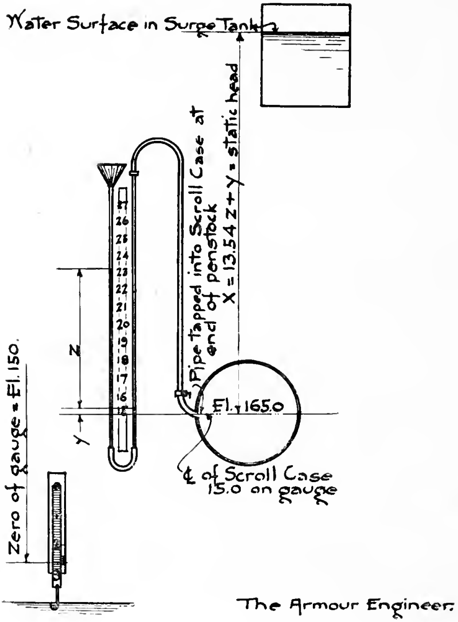


Fig. 9. Diagramatic Sketch showing Position of Gauges for Measurement of Pressure Head on Turbine.

sure head, gives the total effective head on the turbine. The mercury used in the test was tested carefully by the refiners and guaranteed to be of a specific gravity of 13.54. In order to make sure of this figure the mercury column was checked at the beginning and end of each day's test from the known static head on the wheel when same was shut down and no

water passing through. In this case there was no velocity head, and when the other turbines were shut off the difference in height between mercury columns multiplied by the specific gravity of the mercury should give the difference in elevation between the top of the lower mercury column on the right hand and the surface of the water in surge tank. From careful levels this was checked and the specific gravity of the mercury found to be correct as given by the refiners.

READINGS OF PRESSURE GAUGE TUBES AND PITOT TUBES, AND REDUCTION OF VELOCITIES.

Unit No. 2. Test No. 4.

Traverse A (Horizontal)

Calibration of Pressure Gauge 8 in respect of the average readings of gauges

No.	1	2	3	4	5	6	7	8
	—1	—4	—1	—4	0	—6	+1	0

8)—1.5

—.2 = C

Remarks.—In calibrating pressure gauges we find that gauge 8 reads .2 high; therefore we add .2 to the difference, or velocity head, which gives us corrected difference, or corrected velocity head.

Position of pitot tube	Time	B Average piezometer reading in inches	A Average point in inches	(A—B) Difference or velocity head in inches	(A—B)±C Corrected difference or corrected head in inches	Velocity feet per second $\sqrt{\dfrac{2g[(A-B)\pm C]}{12}}$
19	1:37	41.50	51.40	9.90	10.10	7.35
18		41.40	52.50	11.10	11.30	7.77
17		41.20	55.30	14.10	14.30	8.75
16		41.10	56.80	15.70	15.90	9.23
15		40.90	57.50	16.60	16.80	9.48
14		41.15	58.00	16.85	17.05	9.54
13		41.30	57.00	15.70	15.90	9.23
12		41.00	59.50	18.50	18.70	10.00
11		41.15	60.50	19.35	19.55	10.22
10		36.70	58.70	22.00	22.20	10.90
9		36.60	59.80	23.20	23.40	11.20
8		36.90	60.00	23.10	23.30	11.19
7		36.80	58.40	21.60	21.80	10.82
6		36.90	57.10	20.20	20.40	10.46
5		37.40	57.00	19.60	19.80	10.30
4		37.10	53.00	15.90	16.10	9.29
3		37.90	53.90	16.00	16.20	9.31
2		37.50	50.30	12.80	13.00	8.34
1	1:51	38.00	48.50	10.50	10.70	7.56

Table I. Readings and Reductions for Horizontal Traverse 4-A.

Method

In making the test it was determined to divide the cross sectional area of the penstock into ten parts of equal area made up of nine concentric rings or bands and one central circular area. At the center of each one of these rings readings were taken as shown in Fig. 7, thus giving nineteen readings on each horizontal and vertical traverse. In making readings with the pitot tube apparatus the eight pressure gauge tubes on the gauge board were first calibrated with

READINGS OF PRESSURE GAUGE AND PITOT TUBES, AND REDUCTION OF VELOCITIES.

Unit No. 2. **Test No. 4.**

Traverse B (Vertical)

Calibration of Pressure Gauge 1 in respect to the average readings of gauges

No.	1	2	3	4	5	6	7	8
	0	—1	+1	—4	—1	—6	+2	+1

8)—.8

—.1 = C

Remarks.—In calibrating pressure gauges we find that gauge 1 reads .1 high; therefore we add .1 to the difference, or velocity head, which gives us corrected difference, or corrected velocity head.

Position of pitot tube	Time	B Average piezometer reading in inches	A Average point in inches	(A—B) Difference or velocity head in inches	(A—B)±C Corrected difference or corrected head in inches	Velocity feet per second $\sqrt{\frac{2g[(A-B)\pm C]}{12}}$
1	1:52	46.10	56.60	10.50	10.60	7.54
2		38.80	51.70	12.90	13.00	8.34
3		38.70	53.20	14.50	14.60	8.84
4		38.50	54.20	15.70	15.80	9.20
5		38.30	56.30	18.00	18.10	9.85
6		38.30	56.50	18.20	18.30	9.90
7		38.10	59.20	21.10	21.20	10.66
8		37.90	59.60	21.70	21.80	10.80
9		38.10	59.80	21.70	21.80	10.80
10		37.80	58.90	21.10	21.20	10.66
11		38.10	58.00	19.90	20.00	10.35
12		38.00	59.10	21.10	21.20	10.66
13		38.20	58.70	20.50	20.60	10.50
14		38.40	57.20	18.80	18.90	10.07
15		38.90	54.70	15.80	15.90	9.23
16		38.40	55.60	17.20	17.30	9.62
17		38.70	53.00	14.30	14.40	8.78
18		39.20	51.80	12.60	12.70	8.25
19	2:04	39.40	48.00	8.60	8.70	6.83

Table 2. Readings and Reductions for Vertical Traverse 4-B.

respect to the pressure tube adjacent to the pitot tube being used, and by applying a correction to the readings of this adjacent pressure tube the average reading of the eight pressure gauges was obtained, it being found by observation that the pressure gauge columns rose and fell together; thus the average bore a constant relation to this adjacent tube column. The observer then read simultaneously the columns P_h and 8, if the horizontal pitot tube was being operated, or P_v and 1 if the vertical pitot tube was being operated. Two observers working together checked each other's observations, these

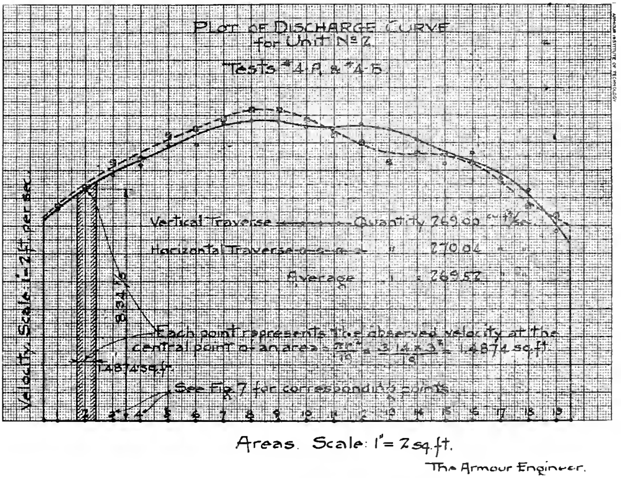


Fig. 10. Plot of Discharge Curve.

being called to two recorders who checked each other's figures at the end of each run. The recorded readings (A — B) +C gave the velocity head in inches. These were reduced to feet, and the velocity, $v = \sqrt{2gH} = \sqrt{2g\,[(A - B) + C]}$ in feet per second, calculated for each of the nineteen points on the horizontal and vertical traverses. Values of the velocities for thirty-eight separate positions of the pitot tubes were calculated from the observations of each run at a given load and gate opening. Tables 1 and 2 show in detail the readings taken and reduction of "v" for runs No. 4-A and No. 4-B,

April 29-30, gate $\frac{45}{80}$ open, load 2700 k.w. In connection with the foregoing and figures No. 2 and No. 7 these tables should be self explanatory.

Calculation of Penstock Discharge "Q"

In order to obtain the quantity of water "Q" from the pitot tube readings, a plot (Fig. 10)of velocities at the several points on the horizontal and vertical traverses was made, using velocities as ordinates and areas as abscissae. A curve was passed through the nineteen points on the horizontal and vertical traverses and the quantity "Q" determined by using a planimeter to measure the area below the curve, which evidently is equal to Σ av between the limits of the penstock sides, or the total quantity of water flowing in the penstock.

Measurement of Head

Throughout the test runs readings were taken on the tail race gauges every fifteen minutes, and on the long and short columns of the mercury gauge every three minutes, the readings in both cases being nearly constant throughout each run. Two observers checked each other and recorded separately at each point. The readings for test runs 4-A and 4-B are shown in detail in Fig. 10.

Time	(a) Short	(b) Long	(c) Tail Race	(b—a)	(a—c)
1:33	18.08	27.68	4.5	....	.....
1:36	18.09	27.67	...	9.58	13.59
1:39	18.08	27.69	...	9.61	13.58
1:42	18.07	27.68	...	9.61	13.57
1:45	18.06	27.69	4.5	9.63	13.56
1:48	18.09	27.67	...	9.58	13.59
1:51	18.09	27.66	...	9.57	13.59
			(4—A)	Av. 9.60	13.58
1:54	18.07	27.69	...	9.62	13.57
1:57	18.05	27.70	...	9.65	13.55
2:00	18.08	27.68	4.5	9.60	13.58
2:03	18.09	27.67	...	9.58	13.59
			(4—B)	Av. 9.61	13.57

4A = horizontal tube

9.60 x 13.54 = 129.984

13.58

Pressure head = 143.564

Area of scroll case at pressure tap =

$.7854 \times (4.67)^2 = 17.13$ sq. ft.

Table 3. Gauge Readings.

Calculation of Efficiency for Test Run No. 4-A

From Table 3:

		Feet
Difference of level of long and short mercury gauge	=	9.60
Equivalent water column = 9.60 × 13.54........	=	129.984
Difference of elevation between top of short column and tail race	=	13.58
H_p = total pressure head	=	143.564

Area of scroll case at pressure tap.

$$A = \frac{\pi d^2}{4} = .7854 \times (4.67)^2 = 17.13 \text{ sq. ft.}$$

Velocity of water in scroll case at pressure tap.

$$V = \frac{Q}{A} = \frac{270.04}{17.13} = 15.82 \text{ ft. per second.}$$

Velocity head.

$$H_v = \frac{v^2}{2g} = \frac{(15.82)^2}{64.32} = 3.891 \text{ feet.}$$

Total effective head of wheel =

$$H_p + H_v = 143.564 + 3.891 = 147.455.$$

Theoretical horsepower =

$$\frac{QWH}{550} = \frac{270.04 \times 62.4 \times 147.46}{550} = 4517.7 \text{ H. P.}$$

Hydraulic efficiency of turbine =

$$\frac{\text{Horsepower on turbine shaft}}{\text{Theoretic horsepower}} = \frac{3663}{4517.7} = 81.1\%$$

Run No. 4-B by a similar procedure gives an efficiency of 82.0%, the average 81.55 is therefore taken as the efficiency of the turbine for $\frac{45}{80}$ gate opening. Fourteen similar test runs with gate openings varying from $\frac{12}{80}$ to full gate $\frac{80}{80}$, and with load varying from 200 k.w. up to 3750 k.w. were made on the test of unit No. 2 and six test runs with gate openings of $\frac{35}{80}$ to $\frac{70}{80}$ and loads varying from 2000 k.w. to 3700 k.w. were made for unit No. 3.

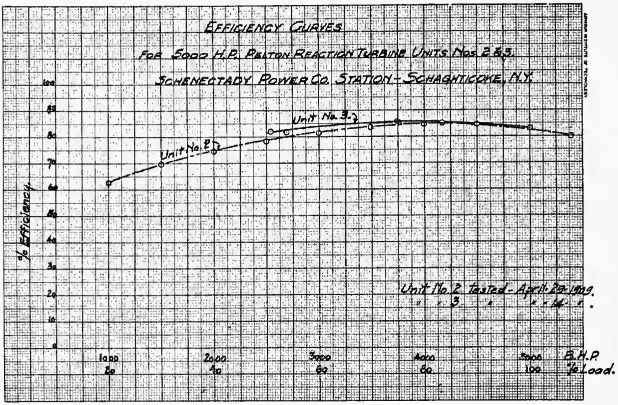


Fig. 11. Efficiency Curves for Turbines.

Electrical Measurements.

In order to insure accuracy, specially calibrated ammeters, voltmeters, and wattmeters were used to measure the power output of the generators during the tests.

The alternators supplied three-phase current at 4,400 volts, and for ordinary measuring purposes current and potential transformers with reducing ratios of 160:1 and 40:1 respectively, were connected between the leads from the alter-

nators to the bus bars and the standard measuring instruments on the switchboard. For test purposes the specially calibrated portable testing instruments we cut in between the transformers and the switchboard.

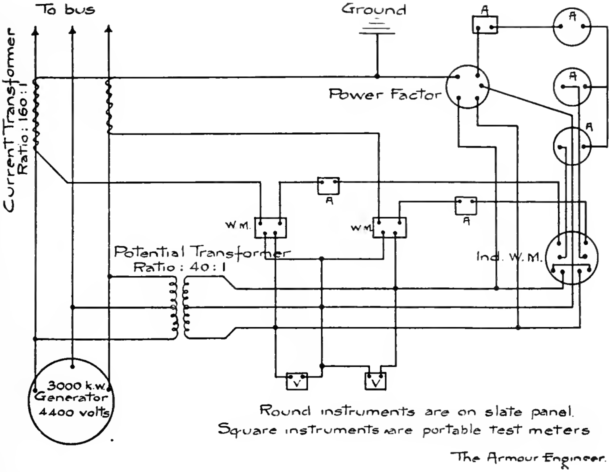


Fig. 12. General Scheme of Connections for Measuring Electrical Power Output

The arrangement of instruments is shown diagramatically in Fig. 12, the regular instruments on the switchboard being shown as circles, and the special test meters as squares. The readings of the wattmeters were used from which to calculate the power developed, and the ammeter and voltmeter readings used for a check on same.

To illustrate the method of calculation the first run of test No. 1 of unit No. 3 will be worked out in detail.

Wattmeter 177503		Wattmeter 159103		
As read	As corrected	As read	As corrected	Time
158.0	156.5	158.0	158.0	2:46
155.0	153.5	157.0	157.0	2:49
153.0	151.5	157.0	157.0	2:52
162.0	160.5	157.0	157.0	2:55

ELECTRICAL READINGS FOR TEST OF 5,000 H. P. TURBINE NO. 3, SCHAGHTICOKE POWER HOUSE.

Generator No. 181794—16 Poles—3,000 K.W.—300 R.P.M. Running in parallel with three other machines of same capacity supplying Schenectady load.

TURBINE GOVERNOR DISCONNECTED AND OPERATED BY HAND.

April 14-09 Time	Cycles Meter 161701	Power Factor Meter 160758	A. C. Ampere Meter 172321	A. C. Ampere Meter 174498	A. C. Ampere Meter 176766	A.C. Volts Meter 177876	A. C. Volts Meter 171242	Watts Meter 177503	Watts Meter 159103	KW at Switch Board	Generator Efficiency taken from V B & B's Curve of Dec. 27, '08	H. P. on Turbine Shaft
2:46	40	99+	1.7	1.7	1.62	109	109.7	158	158			
2:49	40	100	1.65	1.7	1.62	109.5	110	155	157			
2:52	40	100	1.62	1.71	1.6	109.8	110.1	153	157			
2:55	40	100	1.65	1.68	1.63	111.05	111	162	157			
										2007.68	95.32	2883.40
3:46	40	100	1.67	1.7	1.62	109	109.5	156	159			
3:49	40	100	1.66	1.68	1.62	110	110.4	157	157			
3:52	40	99+	1.62	1.68	1.6	111	110.8	157	158			
3:55	40	100	1.6	1.68	1.58	112	110.8	163	158			

Table 4. Electrical Readings during Test No. 1.

Add the watts across the two legs of the circuit:

$$156.5 + 158.0 = 314.5 \text{ watts}$$
$$153.5 + 157.0 = 310.5 \text{ watts}$$
$$151.5 + 157.0 = 308.5 \text{ watts}$$
$$160.5 + 157.0 = 317.5 \text{ watts}$$

$$\frac{314.5 + 310.5 + 308.5 + 317.5}{4} = 312.75 \text{ watts (av)}$$

Since the current transformer has a reducing ratio of 160 : 1 and the potential transformer of 40 : 1, at the current used as shown by the calibration table (Fig. 5), the meters have received only $\frac{1}{160.1}$ of the current and $\frac{1}{40}$ of the voltage of the alternator. The output therefore is $312.75 \times 160.1 \times 40 = 2002.85$ k.w.

For the second run of test No. 1 the output is similarly calculated and the mean of the two results gives 2007.68 k.w. as the average output for test No. 1.

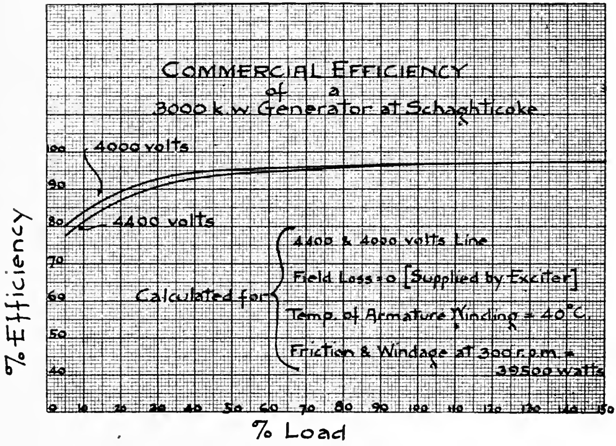


Fig. 13. Efficiency Curves of Generator.

CALIBRATION OF METERS USED ON TEST OF 5,000 H. P. TURBINE NO. 3, SCHAGHTICOKE POWER HOUSE.

Meters Calibrated at General Electric Company's Laboratory

APRIL 13, 1909

April 14-15, 1909.

5 Ampere A.C. Ammeter No. 174498		5 Ampere A.C. Ammeter No. 176766		5 Ampere A.C. Ammeter No. 172321		150 Volt A.C. V. Meter No. 171242		150 Volt A.C. V. Meter No. 177876		5 Ampere Wattmeter No. 177503		5 Ampere Wattmeter No. 159103		Current Transformer Ratio 160:1	
Amp.	Rds.	Amp.	Rds.	Amp.	Rds.	Volt	Rds.	Volt	Rds.	Watts	Rds.	Watts	Rds.	Amp.	Rds.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
1.	.995	1.	.995	1.	1.	50.	49.5	50.	50.2	50.	50.5	50.	50.	1.6	1.0006
1.5	1.5	1.5	1.495	1.5	1.495	70.	69.9	70.	70.1	100.	101.	100.	100.	2.35	.9965
2.	2.005	2.	2.	2.	2.	90.	89.8	90.	90.	200.	202.	200.	200.	2.5	.996
2.5	2.51	2.5	2.5	2.5	2.505	100.	99.8	100.	99.8	300.	302.	300.	300.	3.	.994
3.	3.01	3.	3.	3.	3.	110.	109.8	110.	109.7	400.	401.	400.	399.	4.	.992
3.5	3.505	3.5	3.495	3.5	3.5	120.	119.8	120.	119.9	500.	501.	500.	499.		
4.	4.025	4.	4.	4.	4.01	140.	139.8	140.	139.9						
4.5	4.525	4.5	4.505	4.5	4.505	150.	150.	150.	149.9						
5.	5.01	5.	5.01	5.	5.02										

Potential Transformer Ratio 40:1	Cycles Meter No. 161701	Power Factor Meter No. 160758
Correct	Correct	Correct

Table 5. Electrical Instrument Calibration Table.

$$\frac{2007.68}{.746} = 2691.26 \text{ H. P. on switchboard.}$$

The generator is rated at 3000 k.w. $\frac{2007.68}{3000} =$ 66.92% load on generator. From efficiency curve of generator, (see Fig. 13), determined at factory, we find 95.32% efficiency at this load. Dividing the measured output in k.w. by the generator efficiency we get $\frac{2007.68}{.9532 \times .746} = 2823.40$ H. P. output of turbine at shaft.

Since the wheel is rated at 5000 H. P.,

$$\frac{2823.40}{5000} = 56.5\%$$

Dividing this output by the theoretical horsepower of the water, we have

$$\frac{2823.40}{3473.76} = 81.28\%$$

efficiency of turbine for test No. 1 at 56.5% of its rated loading.

No. of Test	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
Sec. Ft. Water	208.708	277.43	307.43	274.055	379.28	194.565
Effective Head	146.81	146.16	145.42	145.48	143.46	146.63
Theoretical H. P.	3473.76	4597.12	5068.46	4520.09	6169.0	3234.5
K. W. on Sw. B.	2007.68	2824.095	3117.91	2793.415	3682.7	1883.48
H. P. on Sw. B.	2691.26	3785.65	4179.5	3744.52	4936.59	2524.64
Generator Eff.	95.32	96.42	96.68	96.4	96.51	95.11
B. H. P. Turbine	2823.4	3926.21	4323.02	3884.35	5115.0	2654.5
Efficiency Turbine	81.28	85.405	85.30	85.935	82.92	82.07
Per Cent Load	56.5	78.5	86.5	77.7	102.3	53.1

Table 6. Recapitulation Sheet.

Similar calculations for each test at the several loads give the respective efficiencies from which the curve of Fig. 11 is plotted.

Table 6 is a recapitulation of the calculated quantities used to calculate the efficiencies of the respective test runs.

Mr. H. B. Taylor of the I. P. Morris Co., designed the hydraulic testing apparatus used in both tests and had general charge of same.

In the test of unit No. 3, April 14-15, 1909, Mr. H. P. Rust represented the engineers, Messrs. Viele, Blackwell and Buck, assisted by Mr. C. F. Trumbo and the writer, in charge of the installation and operation of the electrical and hydraulic testing apparatus (respectively). Mr. O. A. Harberlin looked after the interests of the Pelton Wheel Co., which furnished the units under test. In the second test of April 29-30 on unit No. 2, Mr. C. F. Trumbo and the writer represented the engineers, Viele, Blackwell and Buck and conducted the test as on unit No. 3.

The writer is indebted to Messrs. M. M. Beck and C. F. Trumbo of Viele, Blackwell and Buck, and to Mr. H. B. Taylor of the I. P. Morris Co., for the data from which this paper is compiled.

THE UTILITY OF THE PYROMETER ON CARBURETED WATER GAS MACHINES.†

By CHESTER S. HEATH.*

The pyrometer is an instrument which is used to measure comparatively high temperatures, such as would be found in blast furnaces, muffle furnaces or retorts, reverberatory furnaces, and in gas machines. In connection with the first three furnaces mentioned, the blast, muffle and reverberatory, the pyrometer has been used for some time as an aid to the daily operations, and considerable literature has been written about the pyrometer as used with those furnaces, but the use of the pyrometer in the daily operation of gas machines is hardly past the experimental stage, and practically no literature can be found upon the subject. It is, therefore, the intention of the author to set forth some of the observations made, and results obtained, in the daily use of the pyrometer since it was first installed in a gas machine under his supervision; namely, since September 1908.

This article is not intended to be a purely scientific treatise on the subject to be discussed, but one which will be of practical value to the man in charge of a gas plant, essaying to give a clearer understanding of the conditions, and temperatures found in water gas machines, and to disclose such improvements in the operations of the machines as have been the result of the use of pyrometers. Consequently, in various parts of the paper commercial terms which are readily understood by men in the gas industry may be used instead of a scientific expression of the same conditions.

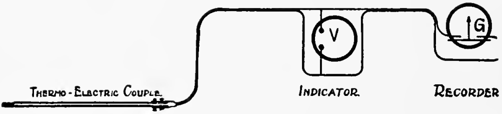
For reasons which will be apparent in the discussion of this paper, the class of pyrometers most adaptable to our use is the thermo-electric pyrometer, consisting of a thermo-electric couple or fire-end, a temperature indicator and a temperature recorder connected in parallel to the fire-end by copper wire. The principle upon which the electric pyrometers are built depends upon the fact that when two wires of unlike metallic composition having differing electrical conductivity are welded or twisted together at one end and this end is subjected to heat, a difference in potential is set up in the cool ends of this thermo-electric couple. If these ends are connected by copper wire an electric current is established through the wire, traveling from the point of high potential to the point of low potential, and when a milli-voltmeter (or galvanometer) is

†Paper read at the Seventh Annual Meeting of the Illinois Gas Association, Chicago, March 15-16, 1911.

*Class of 1907. Asst. Supt. Testing Laboratories, People's Gas Light & Coke Co., Chicago.

placed in the circuit the strength of the current may be accurately measured. When two instruments are placed in parallel so as to read the temperature from a single fire-end of thermo-electric couple, one instrument (for example, the indicator used by the gas maker) is a milli-voltmeter and the other instrument (such as the recorder in the superintendent's office) is a galvanometer.

The strength of the current is proportional to the difference in potential set up in the thermo-electric couple and this difference in potential is proportional to the difference in temperature of the hot and cool ends of the couple. Hence, if the cool ends are kept at a constant temperature the readings on the milli-voltmeter and on the galvanometer will be directly proportional to the temperature of the twisted or welded ends. By proper calibration of the two instruments they may be adjusted to read directly the temperature of the hot junc-



tion in degrees Fahrenheit or in degrees Centigrade. It is readily seen that the two wires of the fire-end must be insulated from each other to avoid the danger of partial short circuits due to the difference in potential of any portion of the wires which may be cooler than the welded end. The wires of the thermo-electric couple may be made of various metals depending largely upon the temperatures to which the couple is to be subjected, although as a rule one wire is a single metal and the other is an alloy, such as the platinum and platinum-rhodium couple, the iron and copper-manganese couple or the nickel and nickel-chromium couple. The composition of the gas which surrounds the couple has no influence on the indications of the instruments.

The purpose of the pyrometer in the gas machine is primarily to aid the operator in maintaining uniform temperatures ("heats," according to work's parlance) in the various parts of the machine, at the best temperature for making gas of a desired quality; and secondarily, to keep the general superintendent in touch with the operations of each gas maker on both day and night shifts, as shown by the recorder instrument. The object of this paper may be divided into the following classification:—

1. A determination of
   a. the most efficient temperature to maintain in manufacturing gas of certain quality.
   b. the effects of carrying other temperatures.
   c. the range of temperature that is practicable.
   d. the limitation of theoretic operation by practical difficulties.

2. Illustration of a method of installation of the pyrometer, so that:
   a. the superintendent while at his desk in the office may always be in touch with the operations of the gas makers.
   b. the gas makers may readily watch and control the temperatures in various parts of the machine without leaving the operating valves.

3. A determination of the exact temperature in various parts of the machine while in operation in order that we may have a clearer and more accurate understanding of gas machines.

4. An exemplification of features other than the temperatures of operation, whereby the use of a pyrometer has been of benefit in practice.

5. A discussion of the results obtained and of subsequent improved methods of operating the machine which are primarily due to the aid of pyrometers, in such a manner as will be of interest to the average gas man and will aid him in an understanding of machine operations even if he has no intention of using a pyrometer in his plant.

Before discussing the question of temperatures most suitable for the proper and practical operation of gas machines it may be well to describe a few of the ordinary conditions and troubles encountered before the pyrometer was used. At that time the gas maker was required to go down stairs to the floor below the charging floor and walk around his machine (in the case of type No. 2) or to climb up two flights of stairs and walk around his machine (in case of type No. 1) to sight-holes where he might look into the machine and judge whether the brick were too hot or too cold; or, whether the oil spray in the carbureter was working properly or was causing "dark streaks" through the checker brick. It will be readily seen that the operator could not make this trip very often and attend to other necessary work, such as proper adjustment of primary and secondary blast valves, regulations of steam pressure and of oil admitted to the carbureter within the limited time of these operations. Very often it is impos-

sible for the foreman to watch the temperatures in each machine, as he has many other duties which demand his constant attention. It may be noted that in stating the fact that the gas maker would judge the temperature of the brick the word "judge" was selected, for the eye may be deceived in many ways as to the true temperature of brick surrounded by a gas or gaseous vapor and judgment at its best, we all know, is subjected to the personal equation. If one authority would say a machine was too cold and another would say it was too hot,

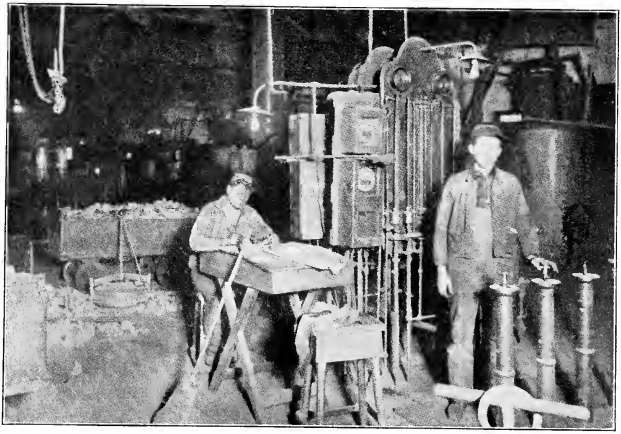


Plate 1. Pyrometer Indicators in Generator House.

(Instruments are located in the center of the picture between the gas maker's desk and the gauge board—the upper one for the superheater and the lower for carbureter.)

what should an ordinary gas maker do? There is no personal equation to a pyrometer, and as previously stated, it indicates the true temperature irrespective of the surrounding gases.

Before the instruments were installed the life of the machine was from 800 to 1000 hours, due to the formation of lampblack in the superheater. The checker brick would often become so thickly coated with carbon that the resultant back pressure would decrease the amount of gas made to a marked degree, often the machine had to be shut down for two days at a time in order to burn out some of the carbon by admitting air through the checkering doors. When the machine was let

down for repairs the bricks would be covered with carbon and ash, burned so hard as to require a pick or sledge and bar at times to remove them from the upper part of the superheater. Strict attention to the temperatures carried in the operating machine and every other known precaution were employed to overcome these conditions, but without results, until the pyrometer told the story. The condition that the pyrometer revealed will be discussed and illustrated in the following paragraphs.

Upon the introduction of pyrometry in the gas industry in Chicago we found that there were three points to be considered in placing the instrument; first, the best position of the fire-ends in the machine; second, the most accessible position of the indicating instrument for the gas maker; and third, the most desirable position of the recording instrument for the superintendent. It was necessary to have two sets of fire-ends in each machine to control the temperatures properly, one in the carbureter and one in the superheater. The carbureter temperature was taken from the lower part of the carbureter while the superheater was taken from top, which at that time was considered to be, and was, usually, the hottest part of the machine. The two indicator instruments (one for the carbureter and one for the superheater) were placed directly in front of the gas maker's stool and beside the gauge board, as is illustrated in Plate No. 1, and connected to the fire-ends by two copper leads 90 feet in length. The recorder instruments for the various machines were placed along the wall in the superintendent's office, as illustrated in Plate No .2, and connected in parallel with the indicator instrument to the fire-ends by copper leads 600 feet in length, which fact illustrates the adaptability of the thermo-electric pyrometer. By this arrangement the gas maker can watch the temperature rise or fall at all times without leaving his operating valves. He can therefore regulate his primary, secondary and superheater blast valves as conditions demand, instead of operating by a "rule of thumb" method. The superintendent by simply turning in his chair is in constant touch with the generator house. He can tell at a glance which machine is down for cleaning; how long each has taken to clean; how the cleaning time compares with the record of previous days; what temperature is carried by each machine in operation during the present run and for any previous run; which machines may not be in operation and how long they have been shut down; what temperatures were carried during the night shift; and how long a machine has been down for repair work. The re-

cording chart may prove of value in case of dispute as to the exact time an accident had happened on a machine and the length of time required to make repairs, especially if the occurrence was during the night shift.

When the first instrument was installed at Pitney Court Station the temperature at the bottom of the carbureter was not carried as uniformly as we now carry the temperatures. (See Plate No. 3 and Plate No. 4 for comparison.) It may be noted that with the pyrometer newly installed and before the gas maker knew its purpose the variation in temperatures while the machine was in operation was not excessive, being

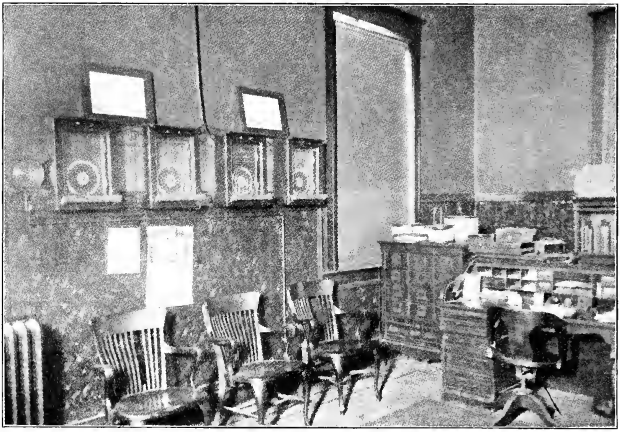


Plate 2. Four Pyrometer Recorders in Office of Gas Works.
(The instruments are located on the wall beside the superintendent's desk fully 600 feet away from the gas machines in the generator house.)

less than 100 degrees for the 24 hours, excepting for the period just after cleaning when the temperature had to be carried low in the carbureter (by blasting more on the fire and using less secondary blast) until the superheater was cooled down to a cherry red color desired. We observe by means of the superheater indicator that the temperature of the upper courses always increase to 1600 or 1800 degrees during the cleaning or clinkering time, an increase of as high as 400 degrees above operating temperatures. This was also noted in the carbureter (as shown by records, Plate No. 5) although not always to such a marked degree as shown in the superheater. When

you are informed that it requires from 6 to 10 hours to bring this excessive temperature down* to the desired 1350 degrees in the superheater (although the carbureter temperature can be reduced in about an hour) you can readily understand that this is the period during which coke is being wasted and lamp black formed with the resulting loss of candle power in the gas manufactured.

Improvements in the methods of handling the machine were then devised to prevent this increase of temperature in the brick work during clinkering. The gas machine had been allowed to stand open to the circulation of a natural draft of air through the carbureter and superheater and out the stack. This air would burn any fine coke dust or lampblack which may have lodged on the brick during the previous period of gas making and thereby raise the temperature of the brick far above good operating conditions. To overcome this trouble the circulation of air through the machine was stopped, on some of the machines by closing down the purge cap and on others by closing the up and down run valves in the hydrogen pipe between the generator and carbureter, according to local conditions. (Note. Before starting to blast through the machine after clinkering a small amount of steam was turned on to cause a circulation through the machine and prevent small explosions of the gases which may have formed.) By this operation an even temperature was maintained in both carbureter and superheater while the stokers were removing the clinkers, but as soon as the blast was put on the generator the excess air for the first few minutes while the fire was still cold would cause an increase in temperature in the machine for the same reasons. This trouble was not so bad as it only took about an hour or two to bring the superheater temperatures down to operating requirements, but since the best operating conditions are none too good from the very first minute that gas is being made and sent into the holders, it was decided to blast on the fires until they were hot enough to make gas without allowing the excess air or comparatively cool blast gases to pass through the carbureter and superheater. To accomplish this the charging doors on the top of the generator were opened and the blast gases allowed to pass through until considerable flame showed above the top of the coke. The primary blast valve was then closed, the up-run

*By means of careful manipulation of the blast valves, such as increased primary blast (because the temperature of the fire is low after cleaning) and decreased, or often no secondary blast with a large loss of heat and waste of coke from excess gases burning at the stack.

valve in the hydrogen pipe or the purge cap as the case may be was opened, the charging doors were closed, a small amount of steam turned on for a moment, the primary blast valve finally raised, and the entire machine was then in the best operating conditions before a cubic foot of gas was sent into the holders. With these changes in the operation we find that the temperature in both carbureter and superheater is almost constant during clinkering excepting for the slight loss due to radiation. (See Plate No. 4—cleaning time from 8:05 A.

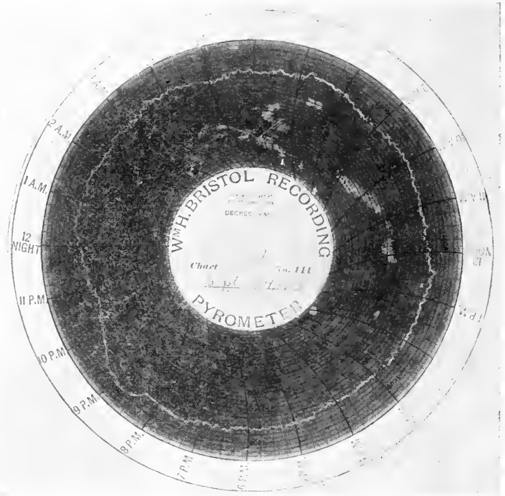


Plate 3.

M. to 9:45 A. M.; also, Plate No. 14—cleaning time from 10:10 A. M. to 12:00 M.

By these improvements in the methods of handling the machine (which you will notice can hardly be called a change in operation during gas manufacture, but rather was a change in the conditions of the machine while idle and when no one would think of watching the temperatures of checker brick) the life of the brick has been increased about 100 per cent and in some cases as high as 175 per cent; and the brick are now quite free from lamp black when the machine is let down for

repairs and recheckering. There is no time lost for gas making, as there is no necessity of burning out any lamp black in the machine. Plate No. 6 shows the clear cut outlines of the brick as removed from an 11-foot water gas machine. In the foreground a portion of the brick from the superheater is shown. The condition of the brick is better illustrated in Plate No. 7. The bricks are arranged in the direction of the travel of gas through the machine, starting at the left side of the Plate. The first was taken from the top course of brick in

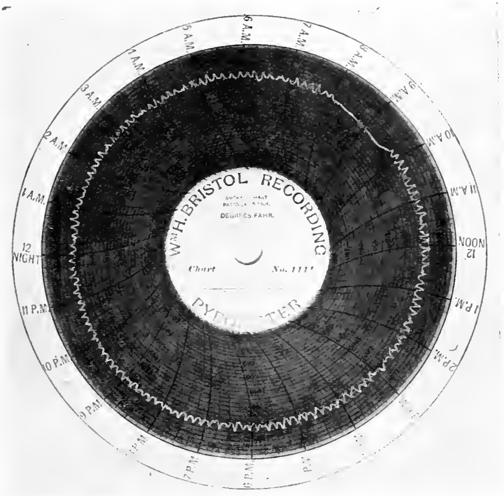


Plate 4.

the carbureter, the second from the middle course, the third from the bottom course, the fourth from the bottom course in the superheater, the fifth from the middle course, and the sixth from the top course. The fifth and sixth bricks have been in the gas machine twice, as the upper half of the superheater is always checkered with old brick. The first brick shows that some of lighter fractions of the gas oil have been burned on the brick, which fact is noticeable only on the first and sometimes second course. This trouble is overcome in a large measure by delaying the admission of oil for a fraction of a minute after the

steam has been turned on, thereby reducing the temperature of the upper courses so that the cold oil will not be over-cracked, or in work's parlance, taking the "sharp heat" off the top courses. When the machine is shut down for repairs the brick immediately begin to cool and may easily be removed by a long handled hook or by hand when sufficiently cold, whereas it previously required two or three days to burn out the carbon and three or four more to cool off the bricks which had become almost white hot by the intense combustion of this fine carbon.

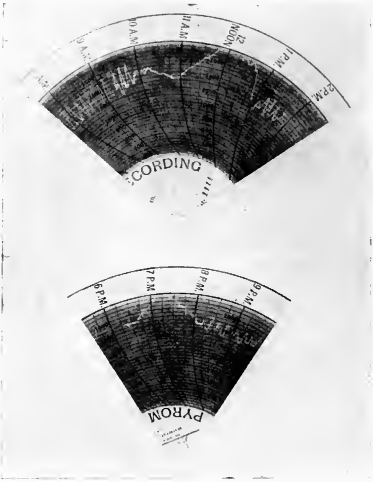


Plate 5.

With the carbureter and superheater checkerwork as free and open the day the gas machine was let down for repairs as it was the day it was started, it became necessary to determine in a general way by means of the pyrometer when the life of the brick was exhausted. When the brick are new there is only a slight drop in temperature in the bottom of the carbureter with the addition of a given quantity of oil but as the brick becomes old the drop in temperature is greater for the same amount of oil used. The following table shows the loss in temperature as indicated by the pyrometer with its fire-ends placed in the middle of the carbureter or nine courses down from the top.

No. Machine	Date when rechekered.	Drop in temperature new brick	old brick
No. 7 Machine	June 1909	150	300
No. 7 Machine	Oct. 1909	200	350
No. 8 Machine	Oct. 1909	250	500
No. 9 Machine	June 1909	250	400
No. 9 Machine	Oct. 1909	125	325
No. 10 Machine	July 1909	175	375
No. 10 Machine	Nov. 1909	200	325

Plate 6. Checker Brick from 11-foot Machine Using Pyrometers.

This increased drop in temperature is due in a large measure to the fact that the heat stored in the brick is not as quickly conducted to the surface of the old brick as it is in the new, and therefore more heat is required from the courses farther through the machine to fix the oil vapors as gases when the brick are old. It will be noted in comparing the

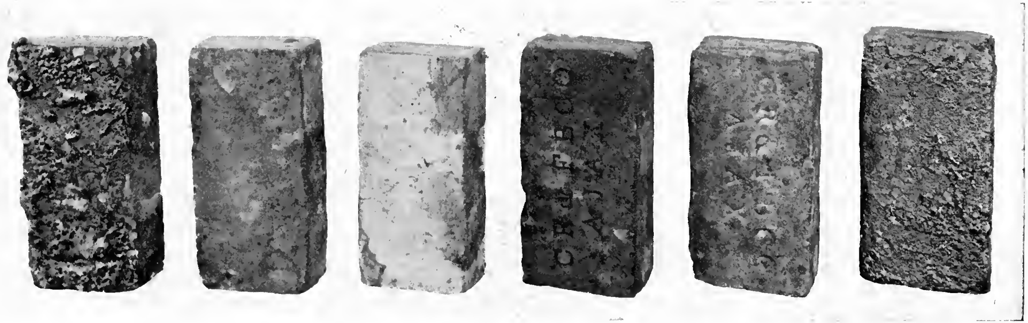


Plate 7. Checker Brick from Gas Machine Using Pyrometer.

(Note the freedom of brick from lamp black. The top course in carbureter shows some burned oil, which is difficult to prevent on the top course; other bricks show a thin layer of reddish dust; the last two bricks have been used twice as the upper half of the superheater is always recheckered with old brick. These bricks have been taken from an 11-foot gas machine after 2400 hours' use in actual gas making time.)

following table with the preceding that although the drop in temperature of the brick is somewhat less in the bottom of the carbureter or 17 courses from the oil spray than it is nine courses from the oil spray when the brick are old, yet the drop is very slight in the bottom course when the brick are new.

No. Machine	Date when recheckered.	Drop in temperature new brick	old brick
No. 7 Machine	Oct. 1909	100	250
No. 8 Machine	Apr. 1909	75	275
No. 8 Machine	Oct. 1909	75	300
No. 9 Machine	June 1909	100	200
No. 9 Machine	Jan. 1910	75	150

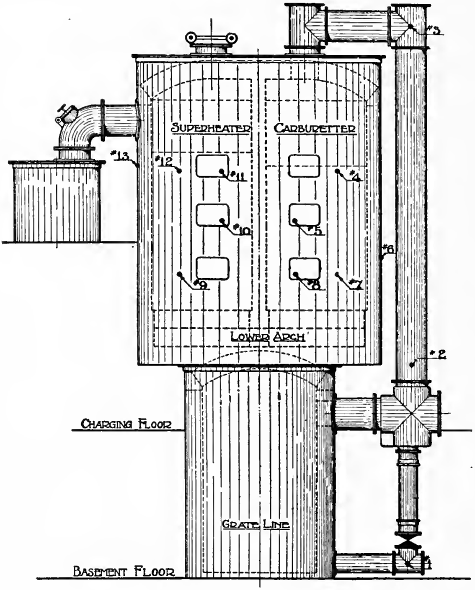
This increase drop in temperature upon the addition of the same quantity of oil per run is a fair indication that the machine needs new checker brick; as the gas work's foreman would say, the machine "won't hold her heats."

In order to obtain information regarding the distribution of heat through various types of gas machines and the variation in temperature at different points in the machine under operating conditions, I took simultaneous records of the temperatures at given points for 14 consecutive days, noting the changes in operation. The diagram of the three types of carbureted water gas machines give a clear conception of the points at which these continuous records were taken. (See diagram of type 1, 2, 3.) The black areas with their corresponding numbers indicate the position of the fire-ends in each type, numbering from No. 1 on, in the direction of travel of gas through the machine.

In type of gas machine No. 1, records were taken of the temperatures of down-run gases at the base of the hydrogen pipe; of up and down-run gases and blast gases in the hydrogen pipe just above the "Williamson" water-sealed hot valve; of the gases at the top of the hydrogen pipe; of the first course of brick in the carbureter; of the 12th course of brick in the carbureter near the center wall between the carbureter and the superheater; of the 20th course of brick at wall; of the 23d course as shown in the diagram; of the 23d the farthest point from, and at right angles to, the center course near the center wall; of the 39th course of brick (39th from the oil spray or 8th from the bottom of the superheater); of the 50th course of brick; of the 61st course near the center wall; of the 61st course away from the center wall; of

the 62nd course at right angles to the center wall (top of superheater.)

In type of gas machine No. 2 records were taken of the temperatures of down-run gases in the generator 4 inches below the grate bars; in the ash pit; and in the hydrogen pipe as indicated in the diagram; of the temperature of up



TYPE Nº 1

Plate 8.

run, down run and blast gases at the top of the hydrogen pipe near the "Levy" valve; of the 9th course of brick from the oil spray in the carbureter; of the 13th course of the 17th course; of the gases passing through the connection pipe between the carbureter and superheater; of the 19th course (or first course in superheater:) of the 56th course (or top of superheater;) and of the gas in the take-off pipe.

In type of gas machine No. 3 readings were taken from

the top course and bottom course of brick in one shell and the bottom and top course of the twinshell.

The average temperatrres obtained by series of tests on type No. 1 water gas machine may be found in the following table. The first column in the table indicates the point at which the temperature was taken (See diagram type No. 1;) the second column indicates the number of courses of checker brick between each position of the fire-end and the oil spray; the third column indicates the maximum temperature at each point, i. e., the temperature attained afer blasting; the fourth indicates the minimum temperature, i. e., at the end of the run; the fifth indicates the loss in temperature at each point upon making gas; and the sixth indicates the average temperature carried at each point.

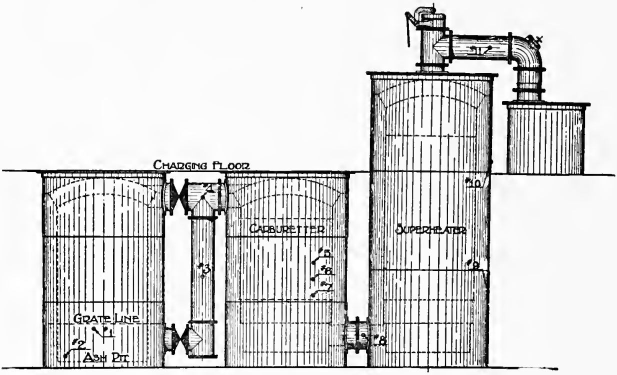
Table No. 1.

Test Point	Course of Brick	Max.	Min.	Drop	Average	Remarks
1					625	Center of 12 in. pipe
					(1610	End of blasting
2					(1360	End of up run
					(720	End of down run
					(1500	End of blasting
3					(1220	End of up run
					(920	End of down run
4	1	1650	1000	650	1270	
5	12	1350	1300	50	1325	12 in. from wall
6	20	1270	1170	100	1220	
7	23	1300	1240	60	1270	
8	23	1335	1300	35	1320	12 in. from wall
9	39	1295	1265	30	1280	
10	50	1310	1300	10	1305	12 in. from wall
11	61	1320	1320	0	1320	12 in. from wall
12	61	1310	1290	20	1300	
13	62	1330	1300	30	1315	

In this type of gas machine carbureter and superheater are built side by side within a single shell, separated by a 14-inch center wall of brick extending from the lower arch up to the top of the machine. There are about 31 courses of brick in the carbureter and 34 in the superheater. It will be noted from the above table that the temperatures are quite uniform

on both sides of this wall, as shown by tests taken at points 5, 8, 10 and 11, and also that the drop in temperature during the run is very small at all these points. Evidently this wall acts as a reservoir of heat tending to maintain more uniform temperatures throughout the fixing chambers.

The first few courses of brick performed the "heavy duty" of vaporizing and cracking the oils as is strikingly indicated by the plotted curve (see Plate 11.) The cooling effect of the oil on the first course is very marked, being about 650 deg .F., while the drop in temperature at the 23rd course (point 7)



Type No 2

Plate 9.

in the same relative position as that taken at the first course (point 4) is only 60 deg. F.

The temperatures of the down run gases taken at the base of the hydrogen pipe (point 1) averaged 625 deg. F., due to the cooling action of the grate bars, blast boxes, etc., as shall be discussed more fully with type No. 2. These down run gases are heated to about 700 deg. F. at a point 3 feet above the "Williamson" hot valve (point 2) and to 920 deg. F. at the top of this hydrogen pipe (point 3) the temperature of these gases is increased by the heat stored in the fire-brick lining of the pipe during the blasting period. The temperature of the blast gases depends very largely on the condition of the fire, as we have known in a general way. When a fresh charge of coke is put into the generator the temperature of the blast gases will

seldom exceed 1000 deg. F., but as each successive blasting increases the temperature of this upper layer of coke, the gases become hotter until they may reach 1750 to 1800 deg. F., as was found after 3 successive up runs. The down run cools off the top of the fuel bed to such an extent that the temperature of the blast gases averaged 100 deg. F. lower than after the pre-

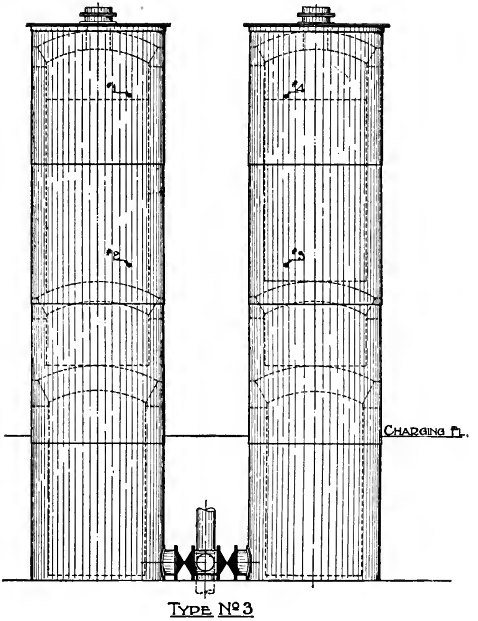


Plate 10.

ceding up run, all other conditions being equal. It was found that the average temperature of the blast gases at the end of the blasting period was about 1610 deg. F. at point No. 2 and about 1500 deg. F. at point No. 3, showing a loss of 110 degrees due to radiation from the hydrogen pipe. The temperature of the up run gases at the end of the run averaged 1360 deg. at point No. 2 and 1220 deg. at point No. 3, a loss of 140 deg. due to radiation.

A test was made to determine the effect of radiation from the shell of the machine upon the temperature of the gases in the checkered chamber, and thereby decide what should be the minimum length of the fire-end. The results are shown in the following table:

Temperatures.

Thickness of shell	At shell	12 in. from shell	15 in. from shell	28 in. from shell	54 in. from shell
18 in.					
18 in.	1230°	1280°	1290°	1300°	1300°

In a gas machine with an 18-inch shell the fire-end should be at least 4 feet long.

The average temperatures obtained by series of tests on type No. 2 water gas machine may be found in the following table:

Table No. 2

Test Point	Course of Brick	Max.	Min.	Drop	Average	Remarks
1					1025	4 in. below grate bars
2					625	In ash pit
3					475	In hydrogen pipe
4		1750	1400		1575	Up run gases
5	9	1650	1150	500	1400	Old brick
		1550	1350	200	1450	New brick
6	13	1500	1350	150	1425	New brick
7	17	1500	1275	225	1390	Old brick
		1450	1350	100	1400	New brick
8	connection pipe	1600	1150	450	1375	Gas Temp.
9	19	1550	1300	250	1425	With Superh. blast
		1375	1275	100	1325	Without Superh. blast
10	56	1350	1300	50	1325	With Superh. blast
		1275	1275	0	1275	Without Superh. blast
11					1225	In take-off pipe

In this type of gas machine the carbureter and superheater are in two separate shells connected at the bottom by a 24-inch pipe lined with fire brick. (See Type No. 2.) The curve plotted from the above table (Plate No. 12) shows very clearly that the top nine courses of brick perform the "heavy duty" in cracking the oils; that the average temperature of the brick is lower the farther the course is from the point at which the oil enters; that the variation in temperature during each run becomes less as the distance from the source of oil

increases; that the variation at the bottom of the superheater is about the same as at the bottom of the carbureter excepting at such times as the gas maker uses the superheater blast for one or more runs when the variation is about 250 degrees. 1*. The loss in temperature in passing through the false bottoms of the carbureter and superheater and the 24-in. connecting pipe

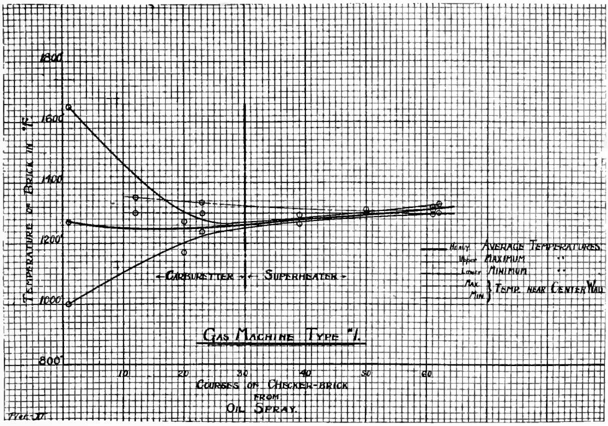


Plate 11. Plot of Temperatures for Type No. 1 Gas Machines.

is clearly shown on the curve. The temperature at the top of the superheater (point No. 10) recorded almost a perfect circle. In the take-off pipe with the fire-end in the cross above the wash-box (point 11) we find that during the run the temperature of the gas averages 1225 deg. when the temperature at point 10 is 1275 deg. F.

It is well at this point of the discussion of the temperatures

1.* Note.—When the superheater blast valve is opened wide the velocity of the air evidently drives the zone of combustion higher than No. 9 hole as the temperature remains about constant for the first part of the blast while the temperature at No. 10 hole rises about 50 degrees. Toward the end of the blast when the carbon monoxide in the blast gases increases, the zone of combustion is brought lower and the temperature at No. 9 increases about the usual amount (100 deg.) If the superheater blast is opened a small amount at first and increased as much as may be necessary during the latter portion of the blasting, the temperature of the brick at point No. 9 increases about 250 degrees, while at No. 10 it increases only 25 deg., indicating that the zone of combustion is lower in the superheater.

of the brick in the two types of water gas machines to compare the character of the two curves. (Plate No. 11 and Plate No. 12.) We find that in type No. 1 machine the oil has been completely "cracked" before it leaves the carbureter and the superheater performs its true function of fixing the gaseous hydrocarbons. In type No. 2 machine the curves indicate very clearly that the oil has not been fully "cracked" in the carbureter; that a large portion of the work must be completed in the superheater, in addition to the "fixing" function of that chamber; and that these partially decomposed hydrocarbons

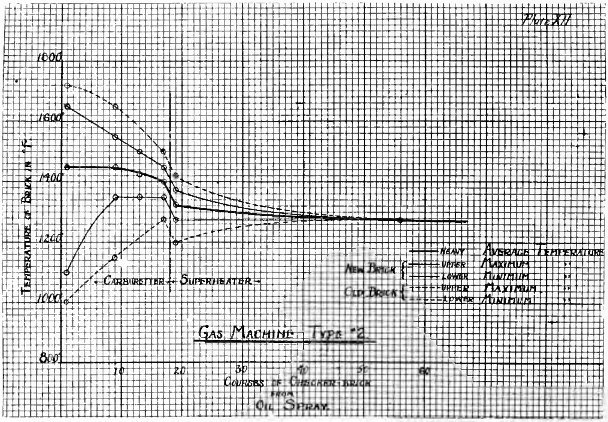


Plate 12. Plot of Temperatures for Type No. 2 Gas Machines.

are subjected to a sudden cooling of about 100 degrees F. in passing through the 24-inch pipe connecting the carbureter and superheater (which condition is not found in type No. 1.) We must therefore conclude that type No. 1 is a much better proportioned machine than type No. 2.

A short description of the test on the temperatures of the down run gases before entering the carbureter may be of interest. The fire-ends were especially prepared to secure the temperatures of the gases quickly and accurately. A half inch iron pipe four inches shorter than the fire-end was used as a jacket to protect and support the long wires. The hot junction extended four inches beyond the open end of this half inch

pipe so as to come in direct contact with the down run gases, while the cold end was held in a stuffing box packed with asbestos at the outer end of the half inch pipe. Three fire-ends, prepared in this manner, were placed in the bottom of the generator about 4 inches below the grate bars (point No. 1); in the ash pit under the blast boxes (point No. 2); and in the hydrogen pipe between the generator and the carbureter (point No. 3); the results of this test (see Table No. 2) indicate much lower temperatures of the down run gases than was anticipated. The clinker and grate bars, cooled by the cold air blast and by the up run steam, decreased the temperature of the down run gases to an average of 1025 deg., the cold blast boxes reduced the temperature of 625 deg. (a loss of 400 deg.); and the radiation from the lower part of the hydrogen pipe reduced the temperature to 475 deg. (a further loss of 150 deg.)

The relative temperatures found throughout the type No. 2 gas machine are illustrated by the Composite Chart (Plate No. 13.) The chart is composed of records taken from eight parts of the machine during the time between 11:30 A. M. and 2:30 P. M., and arranged in the order of the gas travel. The numbers indicate the position of the fire-end in the gas machine from which the records were taken, as shown in the diagram of type No. 2.

The third diagram shown (Plate No. 10) is upon a type of water gas machine which is seldom seen in use at the present day, but it illustrates very markedly the use to which the pyrometer could have been put as a decided aid in operations in the past. This machine has two generators side by side connected by pipes and valves, above each of which is a fixing chamber filled with checker brick at which point oil is admitted for carbureting the gas. Above this short chamber is another, but taller, fixing chamber likewise filled with checkered brick, much for the same purpose as the superheater in the other types. Each shell has its own take-off pipe, purge cap, wash box, etc. When up runs are made the steam enters the bottom of each generator and the two shells are operated as independent machines. When down runs are made the two shells are operated together as a single machine; steam enters the top of the superheater of one shell, becomes superheated steam in passing through the checker brick, is gasified in passing down through one generator and up through the other; a large quanity of oil is admitted in the second fixing chamber and the gases become properly fixed in the upper portion of the twin shell. It will be seen that after a down run the top courses of one shell will always be considerably colder than the other.

To operate two successive down runs, one on one shell and the second on the twin shell, does not overcome this difficulty, as there is always one shell which will have the last down run and that shell will be colder than the other. Here the pyrometer is a great aid if four fire-ends are installed as shown (see Plate No. 10.) The primary and secondary blast on each machine can then be so manipulated with the aid of the four indicators that the colder shell may be brought to the desired temperature without heating the other shell to an excessive temperature during the blasting period. In this type of machine the top of the superheater may be quickly cooled to the desired temperature by reason of the direct effect of the down run steam.

It may be of interest to you at this time to note a few features of more or less importance in the practical operation of a gas machine which I have observed incident to the use of the pyrometer.

The decided advantage a gas maker has in starting a new machine with the constant and accessible aid of the pyrometer by heating the bricks uniformly and gradually throughout the machine without attaining an excessive temperature in the carbureter, is clearly shown by the fourth chart reproduced with this article. (See Plate No. 14.) The record of temperatures at the bottom of the carbureter indicates that the blast was turned through the cold checkerwork at 1 p. m., August 25, 1910, and that the brick were slowly and steadily heated to a temperature of 1350 deg. at this point covering a period of two hours. At 3:40 P. M. the machine was shut down for 10 minutes to readjust the oil meter. From 10:10 A. M. on the following day to 12:00 M. the machine was cleaned and clinkered. Note the absence of any excessive temperatures during the cleaning time, but rather the slight decrease due to radiation.

When gas is made with coke (blasting 4 minutes and running 6 minutes) it is very difficult to detect from the chart, recording the temperatures in the 17th course from the oil spray, just how long the primary blast was used before the secondary was opened; but, when hard coal is used (blasting 6 minutes and running 6 minutes) the chart shows very distinctly the point at which the secondary was opened.

A steam run is readily detected on the chart thus enabling the superintendent to note the carelessness of a gas maker, who may allow the meter to pass an excess of oil for carbureting during a couple of runs and then make the next a steam run to bring the meter statement on the time sheet to the

reading of the meter itself. When the gas makers realize that it is possible to check their work they do become more careful. There is a certain moral influence surrounding the pyrometer, a halo of mystery enveloping that chart over in the office, which the average gas maker greatly respects. He will even refrain from smoking in its presence for some months.

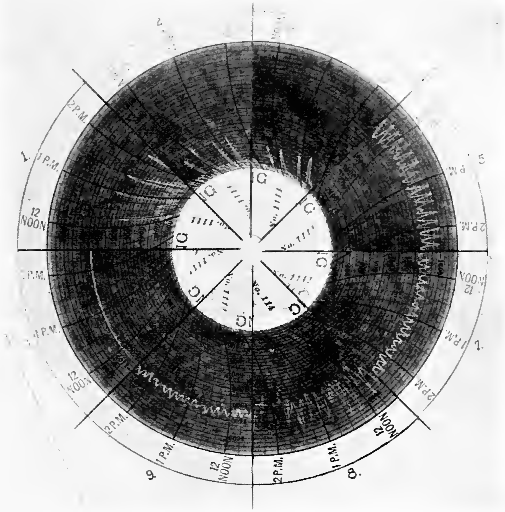


Plate 13. Composite Pyrometer Records of Comparative Temperatures on Type No. 2 Water Gas Machines.

(This chart indicates the temperatures in eight different points on the gas machine from 11:30 a. m. to 2:30 p. m. The numbers designating each segment indicate the relative position of the fire-ends in the machine and correspond to the numbers on Plate No. 9.

Another feature which is readily detected by the carbureter instrument is the action of the oil spray. If it is not properly adjusted, some of the openings become closed with carbon, or the spiral fails to rotate (as in the Johnson spray), the oil will cool the brick in one portion more than another, causing the familiar "dark streaks" in the carbureter. In this connection I might say that the choice between the use of different types of sprays has been simplified in a large

measure. On the one hand a stationary spray was recommended which had no movable parts and required a minimum of repairs but gave a slight "dark streak" in the center of the carbureter, a condition which could not be avoided; while on the other hand a spray was recommended which had to be raised above the carbureter arch after every run to keep it from the heat of the blast gases and which had movable parts, necessitating occasional repairs, but gave no dark streaks when adjusted. The many advantages of the former spray were not of sufficient weight for its adoption when the pyrometer indicated that this "dark streak" represented a temperature about 1000 deg. F., whereas the temperature of the brick 2 feet from the center was 1350 deg. F.

The instruments in the carbureter and superheater aid the gas maker in determining the condition of his generator. If the stack gases show excessive flame at the purge cap (due to the combustion of an excessive supply of carbon monoxide formed in the generator) when the temperatures in the carbureter and superheater are at the desired points, the fire is too hot and the primary blast valve should not be opened so wide during the following blow. When the fire is not hot enough to generate sufficient carbon monoxide to heat the checker work to the desired temperature and to show a thread of blue flame at the stack toward the end of the blow, more primary blast should be given to the generator. By operating in such a manner the pyrometer will aid materially in maintaining a good fire, and reduce the amount of coke wasted by excessive blasting with the primary.

I recall one very interesting incident which occurred about a year ago. The recording chart taken from the instrument on the morning of a sweltering July day indicated a drop in temperature every run or two during the previous afternoon and night. After the oil spray had been examined and found to be in excellent condition, the chart was again referred to and studied more closely. It was noted that there was a certain regularity to the repetition of this increased variation in temperature (about twice the average variation); that it occurred every second and third run in the same order in which the down runs occurred. Upon examination of the hot valve between the top of the generator and the hydrogen pipe, a small quantity of coke breeze was found in the seat of the valve which prevented a tight seating of the gate during a down run and permitted live steam to escape from the top of the generator to the carbureter, causing the increase in the

cooling of the brick during the run. It is needless to say that the trouble was immediately remedied.

Before giving a short summary of the results obtained with the pyrometer in carbureted water gas machines it will be hardly necessary for me to emphasize a few points which I consider of chief importance. Lamp black, I believe, is formed to a large extent when the machine is started up after rechecking with new brick. The heat in the top of the carbureter is allowed to run too high so as to obtain the desired cherry red

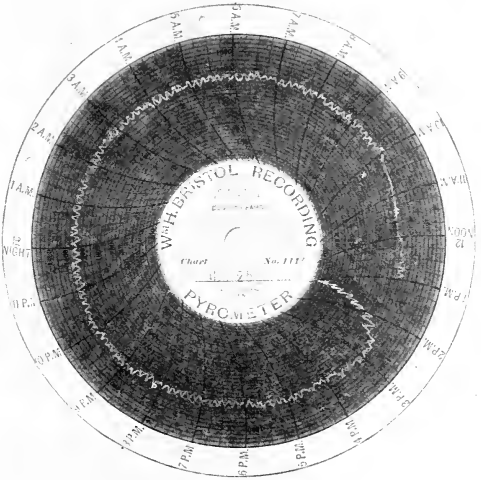


Plate 14.

heat in the superheater as soon as possible. Lamp black is also formed by excessive temperature on the checkerwork after the machine has been idle during the clinkering time caused by the natural draft through the carbureter and superheater. Methods employed to overcome these difficulties have been previously discussed.

The theoretic operation of a water gas set would be the manufacture of gas with as high a temperature as possible in the checker brick without the formation of lamp black and thereby obtain the greatest possible proportion of fixed, gaseous hydrocarbons. In practice we find other factors enter-

ing the problem which limit the temperatures to be carried in the superheater, and it will be noted how narrow these limits are. Temperatures above 1500 deg. F. produce considerable lamp black in the superheater. A machine which carries 1450 deg. F. in the superheater would produce some lamp black and would fill the works with naphthalene in a short period of time. One carrying 1400 deg. F. produces some naphthalene trouble but practically no lamp black. Machines operating from 1300 deg. to 1340 deg. F. produce hardly a trace of naphthalene in the entire plant. Under 1250 deg. F. the machines have dirty seal pots showing tar and uncracked oils. The practical limitations in gas machine control are then complete decomposition of the heavier hydrocarbon oils and no serious trouble from the formation of naphthalene, i. e., clean seal pots and a minimum amount of naphthalene. Best practice keeps the temperature of the superheater between the rather narrow limits of 1300 deg. to 1400 deg. F. These temperatures are based upon the use of gas oil having a gravity between 33 deg. Bé and 35 deg. Bè of approximately the following analysis:

FRACTION	% BY WGT.	SP. GR.	°B.°
From 0° to 300°F	1.79	.7666	54°
300 to 400	6.30	.8016	46°
400 to 500	25.49	.8299	40°
500 to 600	36.12	.8541	35°
600 to 700	24.44	.8820	30°
700 and above	5.86 Residue Tar.		

Sp. Gr. of Oil= .8630 corresponding to 33.2° °Baume

Flash point= 164° °F.

Burning point= 196° °F.

In a general way it may be stated that with a given quantity of oil used to carburet the water gas a temperature of approximately 1250 deg. in the fixing chamber will yield a gas of about 16% methane with correspondingly low heat value, while temperatures approximating 1350 deg. would yield a gas with nearly 20% of methane, and relatively high B. T. U. and

temperatures approximating 1400 deg. would yield a gas containing as high as 22% methane.

In conclusion I wish to summarize in a brief way the principal results obtained by the pyrometer, directly or indirectly, in the practical operation of a carbureted water gas set.

The first and probably most essential point is that a uniform temperature can be maintained in the machine and unless the gas maker has had considerable experience this is a condition difficult to obtain without an instrument.

Second, the carbureting and fixing chambers have been closed during the clinkering time in such a manner as to prevent uneven and excessive temperatures.

Third, methods of operating the blast valves have been devised so as to maintain a healthy condition of the generator fire, with a minimum waste of carbon monoxide gas burning at the stack.

Fourth, the absence of lamp black on the checker work when the machine is shut down for repairs is an indication that the oil for carbureting has been utilized to the best advantage.

Fifth, the freedom of the works from naphthalene has solved many problems, especially the disadvantages of using oxide saturated with the light, flaky crystals in purification of the gas.

Sixth, the gas maker can operate his machine more carefully and intelligently with the constant and accessible indication of the temperatures in various parts of the machine.

Seventh, the continuous record of temperatures carried on each machine by night as well as day shifts in the office where the superintendent may find ready reference, is of untold value.

Eighth, the indicator and recorder will easily show the condition of the oil spray. The charts indicate very clearly the time taken by each machine in charging, clinkering, repairing or waiting.

Ninth, the pyrometer may be utilized to indicate the useful life of the checker brick.

Tenth, a better knowledge of the exact temperatures found in various parts of the machine becomes very useful in practical operations.

Eleventh and final, the extended use of the pyrometer in operating all the machines in the plant under a given temperature for a considerable period of time, and subsequently under other known temperatures for sufficient time, has proven of great value in determining the practicable range of temperature for good operating conditions in the carbureted water gas machines.

THE MANUFACTURE OF PORTLAND CEMENT FROM BLAST FURNACE SLAG.

By RAY S. HUEY, E. E.*

Portland cement is now almost as familiar to the general public as wood or stone, and its uses have become so general and diversified that it has become an invaluable material for durable and fireproof articles in the arts and sciences. The fact that Portland cement is so easily worked, and that almost anyone of average intelligence can do a creditable job with it, makes it a building material for which there is an ever increasing demand. It also has the advantage of being a product, the raw material for the manufacture of which can be found in almost any locality in the world, and if the demand is great enough can be made close to the locality in which it is to be used, thereby reducing the cost of transportation.

Portland cement is a combination of silica, iron, alumina, and lime, in proper proportions, the raw materials of which may be obtained from shale, clay or blast furnace slag and limestone or marl. The process of manufacture, using the blast furnace slag and limestone, at the Buffington plants (Nos. 3, 4 and 6) of the Universal Portland Cement Company, is the one which will here be described.

Many persons are under the impression that the slag from furnaces of any description, blast or open-hearth, can be utilized for making cement, but this idea is erroneous. Slag suitable for cement is very carefully made, and of suitable materials—for example, the slag from a blast furnace using dolomite (magnesium limestone) as a flux cannot be used because the percentage of magnesia in the cement would be too great to pass standard specifications.

Slag is a logical raw material for making Portland cement; it contains roughly 36% silica, 14% iron and alumina, and about 46% lime, is readily fusible, and simply requires the addition of more lime in the proper proportions to make the mixture for first-class Portland cement. It is in a finely divided state, so does not require crushing, and consequently is readily handled. Blast furnace slag suitable for use in the manufacture of cement is made by allowing the molten stream of slag to run from the furnace to a tank where, as it falls off the trough, it is struck by a stream of high-pressure water which cools and disintegrates it immediately. It is then loaded

*Class of 1899. Asst. Superintendent Plants 3, 4, and 6, Universal Portland Cement Co., Buffington, Ind.

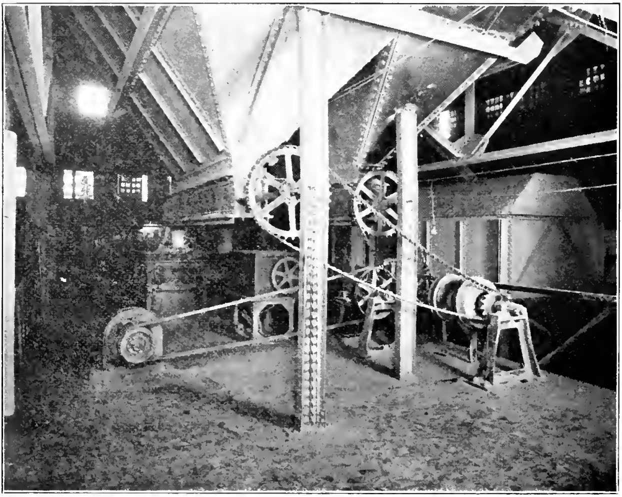
into hopper-bottom steel freight cars by a traveling crane, which digs the granulated slag out of the water by a clamshell bucket, and shipped to the cement plant where it is dumped from a trestle into large bins. The slag is in small particles, slightly resembling sand in size and color, and contains a large percentage of water, varying between 20% and 40%—depending upon the physical character of the particles and the temperature at which it was granulated.

Granulating the Slag at the Blast Furnace.

This slag is discharged from the raw material bins into elevators which carry it to the dryers, these being slowly revolving cylinders having compartments lined with flights which turn the material over and over and keep it traveling toward the discharge end, allowing hot gases to come in contact with the wet slag and drive off the moisture.

The slag is now elevated again in bucket elevators and spouted to various ball mill feed hoppers which are intended to keep a sufficient stock in them to keep a mill supplied for some time, should the preceding machine which supplies the hopper have to be shut down for repairs. The slag is preliminary ground in a ball mill, conveyed to an elevator by a belt con-

veyor, and again elevated to hoppers over the weighing machines or scales. The ball mill consists of a pair of steel discs mounted on a shaft about 5′ apart, having 20 heavy cast-steel wearing plates mounted near the circumference. Ten of these plates are solid and ten are perforated, and are mounted in such a way that when the 4,500 pounds of 4″ steel balls fall on the material to be crushed, some will be crushed and go through the perforated plate. Between the steel wearing plates and the periphery of the disc are two sets of screens, consisting



Scales for Weighing the Raw Material Mixture.

of one set of heavy protecting screens of perforated metal which protects the lighter and finer wire-cloth screen on the outside from injury in case a steel plate breaks, and which also takes the wear off the lighter screen from material which could not possibly go through the fine screen. All the material which does not go through is returned to the plates and crushed until it will go through.

The limestone, which is the other ingredient of the raw material mixture, is quarried at the Company's quarry in the Fairmount District, crushed to about a 6″ cube or smaller, shipped in steel hopper cars and unloaded into the trestle bins

in the same manner as the granulated slag. It is then crushed to about 1½″ in a gyratory crusher, elevated to a dryer, dried and ground in the same manner as the slag.

The dried slag and stone are in separate bins above a pair of tandem, automatic, electrically operated scales, and are conveyed to the scale hoppers by means of screw conveyors. The scales are arranged so that a contact is made with a dumping mechanism, which discharges both scale hoppers simultaneously after both are up to full weight. The material is then mixed and carried by a screw conveyor from a hopper below the scales to a bucket elevator which spouts the mixture to the tube mill hoppers.

The final raw material grinding is done in tube mills, each of which is a tube 5′ or 6′ in diameter and 22′ long, and lined with hard cast-iron plates bolted to the shell. The shell is supported by a head at each end on which is a hollow trunnion, the material being fed into the trunnion at one end and discharged through the one at the other end. This mill is about half-filled with flint pebbles and is revolved at about 25 revolutions per minute, thus causing the material to be crushed to a fine powder by the falling of the pebbles on it. The finished raw material mixture is taken on a belt conveyor to an elevator, and then across a bridge by a screw conveyor to the hoppers over the feed end of the rotary kilns in the burner building.

The kilns are steel shells lined with fire-brick about 7′-6″ in diameter and 120′ long, and are set on a pitch, which, when the kiln is revolved, tends to move the material toward the lower end. The kilns turn around once per minute and by the time the material is discharged at the lower end it has been fused by intense heat into balls called clinker. The rotaries and dryers are heated through the combustion of pulverized coal blown in by an air-blast, this producing a flame that appears very much like a big gas flame and a temperature of about 2350° F. at the hottest end of the kiln.

The pulverized coal is produced by crushing and drying coal screenings and then pulverizing them in fuller mills, one of which consists of a vertical shaft having mounted on it a spider which pushes four 9″ balls around a hard cast iron ring with sufficient velocity to furnish the necessary centrifugal force to crush the coal. By means of a fan attached to the main shaft above the balls the fine coal is blown through the screens.

The clinker is now elevated and spouted into a large open bin holding about 75,000 barrels, and is picked up and dis-

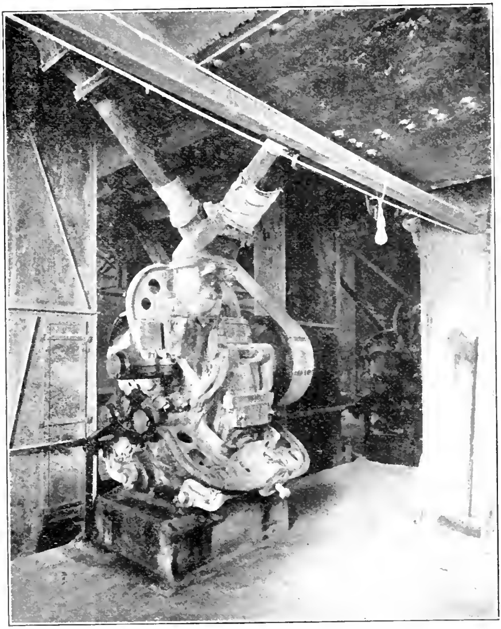
tributed by traveling cranes, to which are attached large clam-shell buckets. While on the pile the clinker is sprinkled with water until it contains about $1\frac{1}{2}\%$ moisture, this being to slack out the free lime which is always present in small amounts in fresh clinker. When properly seasoned, it is picked up again by the cranes and put into the hoppers over the clinker crushers in the finishing mill. In jaw-crushers, the large lumps are crushed to about 1″ in diameter, and the clinker falls into the Maxecon mills, to be granulated.

Rotary Kilns in Burner Building.

The Maxecon mill is a machine composed essentially of a ring having a concave inner surface, and three rolls having convex outer surfaces made of hard material. The rolls are set 120° apart and pull out against the inside of the ring. The tension between the ring and the rolls is regulated by a spring, each one of which reacts between the frame of the machine and a yoke on which are mounted the bearings for the shaft holding each roll. The top roll is driven, and this through friction drives the ring which in turn drives the two bottom rolls. The material to be crushed is fed in between the ring and one roll and the centrifugal force carries it around inside of the ring to the next roll, this continuing until it drops off through the frame to the elevator. The elevator then lifts the crushed ma-

terial to a screen in which the fine material is separated and taken to the gypsum scale. The coarse material remaining is returned to the Maxecon mills to be crushed again.

By means of automatic weighing machines about 2% gypsum (calcium sulphate) is added to regulate the setting time of the cement. Cement without gypsum would set in about 3 or 4 minutes, so it can readily be seen that it would be useless to work with as a building material, for the most rapid



Maxecon Mill for Preliminary Grinding of Clinker.

mixer and workmen would be unable to mix and place the concrete before it would set.

From the gypsum scales the ground clinker is again elevated to the hoppers over the tube mills and given a final grinding. The cement in this condition is finished and is conveyed by a belt conveyer from the tube mills to the storage

bins in which it is kept until required for shipments. When this is desired it is drawn out from the bottom of storage bins, through gates into the screw conveyors to elevators, thence to packing hopper, packed by automatic weighing machines into ¼-barrel sacks, either in paper or cloth, and loaded into cars for shipment.

The total combined capacity of all the plants of the Universal Portland Cement Company is 40,000 barrels per day, of which 27,000 are made at Buffington, in Plants 3, 4 and 6. This requires about 200 cars of raw material, and about 100 to 300 cars, depending on the season of the year, are required every day in which to ship the finished product.

The finished cement is sampled by an automatic sampler once every eight seconds, and this sample taken to the laboratory every hour where complete tests for fineness, setting time, and soundness are made. Every car is sampled before shipment, and the same tests made in order that there may be complete records for reference. About 96% of the finished cement will pass through a 100-mesh sieve, which has 10,000 holes per square inch—the diameter of the wire forming the sieve being .0045″. About 80% will pass through a 200-mesh sieve, having 40,000 holes per square inch—the wire in this case being .0024″ in diameter.

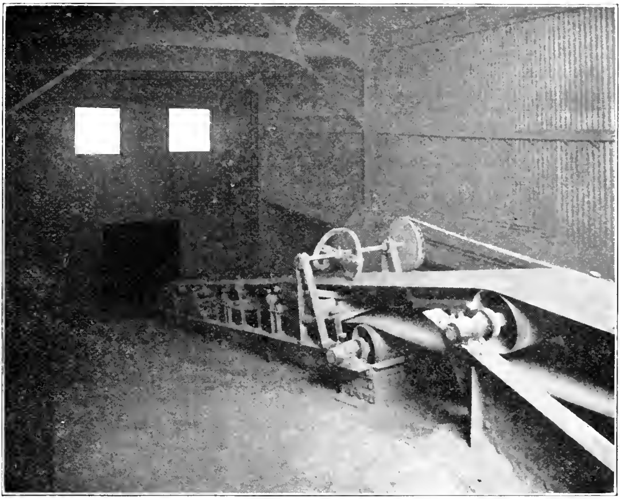
Chemical analyses are made continually to keep the ingredients in the raw material constant, and strength tests and analyses are made daily to see that the quality is kept up well above the standard requirements.

All the machinery is electrically driven, and requires approximately 10,000 H. P. at the sub-station switchboard. The power required is generated by the waste gas from the blast furnaces, by either steam engines, steam turbines or gas engines, and transmitted ten miles at 22,000-volts, 3-phase, and 25-cycles, to the sub-station in which it is transformed to 440-volts and distributed to the different buildings by independent switches, so that in case of trouble in one building it can be disconnected and the trouble remedied. The machines are individually driven and as far as possible direct connected, thus eliminating many belts and geared speed-reducing devices. This makes it possible to shut down each machine for repairs, when necessary, without disturbing the rest of the mill, and so allows the mechanical department to keep the plant in a better state of repairs.

The motors are all of the squirrel-cage induction type and give very little trouble under the severe loads and dust conditions which are found in a cement plant. The progress made

in the improvement of machinery for grinding cement has been remarkable in the last ten years and nearly all the machinery installed then is now out of date.

From a college man's standpoint a cement plant is an interesting place. To be a successful operating man at the head of a large cement plant, he should be a chemical, mechanical and electrical engineer combined, and the more thorough the ground-work the more capable man he will be. In detail, re-



Device for Automatically Sampling Cement.

garding the engineering qualifications of the head of such a plant, he should know the effect of certain variations of the raw material. It is also necessary to know the effect of the chemical constituents of the steel and other materials which are used in machinery, in order to get the most efficient and durable material to be used in new machinery, or in making repairs. As a mechanical engineer he is called upon to figure strength of parts, size of pulleys, capacity of machinery, and design new improvements.

Since my connection with the cement plant, my viewpoint regarding machinery has been entirely revolution-

ized. I formerly thought that when a machine was purchased it was ready to do the work for which it was designed without any changes. I have found, however, that with few exceptions there is hardly a machine on the market which does not need reconstruction to make it better and more adaptable to the work required of it and there is frequently a small detail, the lack of which will make it a failure. It is here that a thorough knowledge of mechanical engineering coupled with a practical experience gained under individual conditions is valuable. It is therefore necessary to scrutinize carefully the detail drawings of every machine and try to see in one's mind whether the design of a new machine cannot be altered to adapt it to the work to be performed in your particular plant, as most machinery seems to be designed by persons who have had little practical operating experience, and consequently know but little of the difficulties which are encountered in the operation of their own machinery.

On account of the increasing use of motors and electrical apparatus in connection with the cement industry, if one is to be familiar with the details of the work under him he must be qualified to pass on the design of motors and transformers and all kinds of improved electrical apparatus which must be built to suit certain conditions. He must be able to design and calculate new installations and make specifications to meet his peculiar requirements. He must also know how to diagnose electrical troubles and prescribe the cure. When one is qualified to meet all the above specifications, he still has the most difficult problem before him, which is that of handling men. To have a good organization which will pull together and produce results at a minimum cost, is the goal of every man in an executive capacity, not only in the cement industry, but in every other kind of business.

SYNTHETIC CAOUTCHOUC.

By FRANK E. BARROWS.*

(A Review Compiled from the Literature.)

It may be well at the outset to define what is meant by "Synthetic Rubber" or "Synthetic Caoutchouc." The India-Rubber Journal, Vol. 34 (1907), p. 519, defines it as a substance "built up by chemical means, * * * and possessing all the physical and chemical properties of natural rubber." If we consider, however, the molecule of the natural rubber hydrocarbon as having an empirical formula $C_{10}H_{16}$, it will be necessary to modify this definition somewhat to include other products having all the physical properties of natural rubber but whose chemical properties, owing to variations in empirical or structural formulae, may be either identical with, or analogous to, those of the natural caoutchouc. The existence of the so-called homologous caoutchoucs, probably differing in empirical formulae from that given above, will be hereinafter referred to more at length.

Synthetic rubber, then, is the product of a chemical process as distinguished from the natural product which is obtained from the latex of rubber-producing plants. In composition and properties, however, the synthetic product may be considered the same as, or equivalent to, the pure india-rubber hydrocarbon.

The distinction between the real synthetic rubber, and the so-called artificial rubbers and rubber substitutes should be kept clearly in mind. These latter, which are sometimes improperly called synthetic rubbers, generally possess some of the physical characteristics of natural rubber, but may not be even remotely related to it chemically. They may consist either of a greater or less percentage of natural rubber together with various fillers and diluents, or they may consist entirely of vulcanized oils or gums.

It is the purpose of the present article to review, more or less completely, the literature which has up to the present time appeared on the subject of synthetic rubber, its formation and constitution.

It has long been known that an intimate relationship exists between isoprene and caoutchouc, isoprene being one of the products of the destructive distillation of caoutchouc, and being itself capable, under suitable conditions, of being again converted into caoutchouc by polymerisation. Many experiment-

*Formerly of Class of 1910. Assistant Examiner, U. S. Patent Office, Washington, D. C.

ers have observed these phenomena. It is therefore natural that the term "synthetic rubber" should first suggest the product made from isoprene. A discussion of this hydrocarbon, and of the caoutchouc made from it, will, therefore, first be given.

Isoprene, as is well known, has the structural formula $CH_2:C(CH_3).CH:CH_2$, corresponding to the empirical formula C_5H_8. It is a member of the diolefin series of hydrocarbons, containing two double bonds, and is chemically beta-methyldivinyl, or 2. methyl-1.3-butadien. It was first identified and studied by Williams in 1860 (J. Chem. Soc., 1862, Vol. XV, p. 110), who isolated it from among the products of the destructive distillation of caoutchouc. Mention of its polymerisation was also first made by Williams at this same time. He observed that when isoprene was left standing for some months it absorbed oxygen from the air, became viscid, and acquired powerful bleaching properties. When this product was carefully distilled, unchanged isoprene first passed over, the temperature suddenly rose with evolution of ozone, and the contents of the retort solidified to a pure white, spongy elastic mass having but slight tendency to adhere to the fingers. When burnt it gave the characteristic odor of caoutchouc. The composition of the oxidized product (apparently before removal of the ozone from it), was found, on careful analysis, to be C_5H_8O.

The next recorded polymerisation of isoprene was in 1879 when Bouchardat studied the action of the haloid acids on it. (Comptes rendus, 89, 1117-1120). When dry hydrogen chloride gas was slowly passed into isoprene at 0°, it was slowly absorbed and from the resulting product there was obtained some of the unchanged hydrocarbon and a large amount of the monochlorhydrate of isoprene, C_5H_9Cl, boiling at 86-91°. Under these conditions (3 hrs. action) the formation of a substance of higher boiling point was not observed.

On the other hand, when saturated hydrochloric acid at 0° acted on isoprene for 15-20 hours in a sealed tube with occasional agitation, and the resulting product was distilled, a solid residue, in appreciable amount, remained behind.

This solid residue persistently retained about one per cent of chlorine, its analysis otherwise giving the same percentage composition as isoprene. (C=87.1; H=11.7; Cl=1.7). It possessed the elastic, and other characteristics of caoutchouc; it was insoluble in alcohol, swelled in ether, and dissolved in carbon bisulfid in the same manner as natural caoutchouc. When submitted to dry distillation it gave the same volatile hydrocarbons that caoutchouc gives. All these properties seem to identify this isoprene polymer with the parent material of the isoprene itself, caoutchouc.

It should be observed, however, that in the above reaction in which the caoutchouc was obtained, the principal products of the reaction were the mono- and di-chlorhydrates, while the caoutchouc was merely a by-product, constituting not over one-sixth of the resulting product.

Hydrobromic acid, in saturated solution, was found to act in the same way as hydrochloric; it formed the elastic polymer which retained not over two per cent of bromine.

Fuming hydriodic acid acted very violently on isoprene. The elastic polymer was apparently formed, but not isolated.

Tilden, in 1882 (Chem. News, Vol. 46, p. 120), first reported the formation of isoprene by the depolymerisation of turpentine, the turpentine vapors being passed through an iron tube heated to redness. Only 20 cc. of the isoprene fraction, however, were obtained by this process from a liter of turpentine. The isoprene thus obtained was found to act in the same way as the isoprene from caoutchouc, and gave a tough substance closely resembling caoutchouc when acted on by concentrated hydrochloric acid. The conversion of isoprene to caoutchouc by nitrosyl-chlorid is also reported by Tilden in this article.

Again in 1884 (Trans. Chem. Soc., 1884, p. 410), Tilden reported his further study of the products obtained by the decomposition of turpentine vapors by heat. As in the former experiments a small amount of isoprene was obtained (200 cc. isoprene from 4 liters turpentine). The turpentine vapors were passed through an iron tube heated to the lowest possible redness just visible in a darkened room. Benzene, toluene, m-xylene, cymene, and terpilene were among the other products identified. About 15% of the product boiled above 200°, and was not further studied. Nearly 30% of the product was lost in the form of gas. If the iron tube in these experiments was heated to visible redness or to a higher temperature isoprene was no longer found in the products formed. It does not appear that a yield of as high as 10% of isoprene was ever obtained by this process (Tilden, India-Rubber Jour., 36 (1908), p. 322). This isoprene, as in the case of the preceding experiments, was converted into caoutchouc by polymerisation, contact with strong acids in the cold effecting the change.

In 1885 Wallach (Annalen der Chemie, 238, p. 88), found that isoprene, when it remained placed in the light for a long time, polymerised, and on adding alcohol to the resulting product there separated out a caoutchouc-like mass which hardened on exposure to the air.

Apparently unaware of Wallach's experiments Tilden in

1892 (Chem. News, Vol. 5, p. 265) reported a similar observation of the spontaneous polymerisation of isoprene in the following language

"I was surprised a few weeks ago at finding the contents of the bottles containing isoprene from turpentine entirely changed in appearance. In place of a limpid colorless liquid the bottle contained a dense syrup, in which was floating several large masses of solid of a yellowish color. Upon examination this turned out to be india-rubber. The change of isoprene by spontaneous polymerisation has not to my knowledge been observed. I can only account for it by the hypothesis that a small quantity of formic or acetic acid had been produced by the oxidising action of the air, and that the presence of this compound had been the means of transforming the rest. The liquid was acid to test paper, and yielded a small portion of unchanged isoprene.

"The artificial indiarubber, like natural rubber, appears to consist of two substances, one of which is more soluble in benzene or in carbon bisulfid than the other. A solution of the artificial rubber in benzene leaves on evaporation a residue which agrees in all characters with a similar preparation from Para rubber. The artificial rubber unites with sulfur in the same manner as ordinary rubber, forming a tough elastic compound."

Tilden's observations of the spontaneous polymerisation of isoprene were later confirmed by Weber (Jour. Soc. Chem. Ind., 1894, Vol. 13, p. 11). From 300 gms. of isoprene Weber obtained, after nine months standing, and by treatment of the resulting viscid, treacly mass with alcohol, a solid spongy substance of almost white color, which on drying became a light brown and was in all respect identical with indiarubber. The weight of indiarubber thus obtained was 211 gms. The principal by-products were dipentene and polyterpenes,—products of very little value.

Again in 1906 (Chem. News, 94, p. 90) Tilden reports that the spontaneous polymerisation of isoprene to caoutchouc takes place slowly, requiring several years. He further states that if any attempt be made to hasten the operation, as by heat or contact with strong reagents, the greater part of the hydrocarbon is converted into dipentene, and a mixture of viscid compounds of high boiling points known as colophene,—the same product as results from the polymerisation of the terpenes.

To the same effect is a further communication from Tilden

in the India-Rubber Journal, Vol. 36 (1908), pp. 321-2. A review is here given of his prior experiments to date, together with a letter from which the following is excerpted,—

"The conversion of isoprene into rubber occurs, so far as observed, under two conditions, (1) When brought into contact with strong aqueous hydrochloric acid or moist hydrogen chlorid gas; (2) By spontaneous polymerisation.

"In the former case the amount of rubber produced is small, and it is only a by-product attending the formation of the isoprene hydrochlorids, which are both liquid. In the latter case the process occupies several years.

"Of course many attempts were made by me to hasten the process, but it was found that contact with any strong reagent, such as oil of vitriol, pentachlorid of phosphorus, and others of milder character, led only to the production of the sticky 'colophene,' similar to the substance which results from the polymerisation of the terpenes, and after a course of experiments which were carried on for about two years, I was reluctantly obliged to abandon the subject."

A more recent process for the production of caoutchouc from isoprene is that of Harries, India-Rubber Journal, May 16, 1910, pp. 630-1. This process, together with the route which led to its discovery, is described as follows:—

"I have shown you that the insoluble caoutchouc can be converted into the soluble form by boiling with glacial acetic acid. So I came to the conclusion that an equilibrium occurred, for whilst caoutchouc is truly depolymerised by acetic acid, then, however, it is equally reconverted into rubber. From this point of view I likewise heated isoprene with glacial acetic acid, and as it is very volatile I employed a closed tube. I now observed that rather over 100°C a product separates which is actually rubber. It was noticeable that pure synthetic isoprene is polymerised more readily than natural isoprene from rubber. Later I found yet other methods. If the conditions, however, are not strictly adhered to, all sorts of thick greasy oils, resins and gums are obtained, which are not rubber. * * * The artificial rubber is quite as tough and elastic as the natural product, and of a light brown to a white color."

The ozonide and nitrosite formed from this synthetic rubber also corresponded with those from natural rubber.

Another report of the spontaneous polymerisation of isoprene to caoutchouc was made by Pickles in 1910 (Trans. Chem. Soc., June, 1910, pp. 1086-7), the polymerisation having been effected by standing, for the greater part of the time in the dark, for three and a half years. All the numerous tests applied to the

product thus obtained, and separated from the viscous polymerised mass by alcohol, identified it as the same in composition and properties as natural caoutchouc.

Lebedeff, in a still more recent article, to be hereinafter referred to more at length, has obtained the caoutchouc polymer from isoprene by heating in a closed vessel at 150° for several days.

Turning now from the periodical to the patent literature, we find that the first patent for synthetic rubber was the Br. patent to St. George, 15, 544, of 1892. According to this patent turpentine vapors are passed through a heated tube and condensed by a spray of hydrochloric acid; or the vapors are condensed and then agitated with hydrochloric acid to give the solid caoutchouc. In the light of Tilden's experiments it is probable that isoprene was formed in this process as an intermediate product.

The Heinemann patents, Br. 21,772 of 1907, and French 394,795, describe the condensation of isoprene to caoutchouc by concentrated hydrochloric acid. According to these patents acetylene and ethylene, when passed through a heated tube, give divinyl, which is converted into methyl divinyl or isoprene by treatment with methyl chlorid; or the three gases may be passed through the tube together to effect the same result.

A still more recent patent for the production of caoutchouc from isoprene is the French patent 417,170, to the Badische Anilin & Sodafabrik, according to which isoprene is heated either alone for 20 hours at 120°, or with 10% of its weight of conc. caustic soda at 100°. The caoutchouc is separated by precipitation with alcohol, or by steam distillation of the unchanged isoprene.

The hydrocarbon, next to isoprene in point of interest in connection with synthetic rubber, is diisopropenyl, or the 2.3-dimethyl-1.3-butadien, $CH_2:C(CH_3).C(CH_3):CH_2$.

Couturier in 1892 (Annales de Chimie, 6 Ser., Vol. 26, p. 489) described this hydrocarbon in the following language, the hydrocarbon having been obtained in small amount by the dehydration of pinacone.

"Beta-bipropenyl polymerises with extreme ease. * * * This property renders all reactions with this hydrocarbon difficult. The polymerisation is effected by heat alone, and the liquid is transformed into a viscous product which does not distill. Chloride of calcium acts even without heating, when left for a long time in contact with the hydrocarbon."

With sulfuric acid Couturier obtained resinous polymers.

The preceding brief description is valuable as indicating

the peculiar properties of the hydrocarbon. Of even more interest, however, are the two articles by Kondakoff in Journal für praktische Chemie, 62 (1900), p. 175, and 64 (1901), p. 109.

The first of these articles describes the heating of the hydrocarbon with alcoholic potassium hydroxide (1:KOH, 3:EtOH) to 150° for 5 hours. A part of the hydrocarbon remained unchanged; a part was polymerised to a white leathery elastic mass, insoluble in water, but soluble in hydrocarbons, ether and alcohol, and which did not distill with steam. The similarity of this product to caoutchouc was noted.

Again in the second article Kondakoff records a similar polymerisation of this same hydrocarbon, by letting it stand in a closed bottle in diffused light for about a year. The hydrocarbon in this case was completely converted into a solid white spongy mass. Under the microscope this mass appeared amorphous; it was tasteless and odorless and as elastic as caoutchouc. It did not appear to undergo change in the air and was entirely insoluble in benzene, ligroin, chloroform, carbon bisulfid, ether, alcohol, acetone and oil of turpentine, swelling only in benzene. The author observed that this polymer appeared to be a higher product of polymerisation than the one referred to in the preceding article.

The polymerisation of this same hydrocarbon into its caoutchouc-like polymer has also been effected by heating for several days under pressure. An account of such polymerisation is reported by Lebedeff in the article referred to below.

The most recent publications on the polymerisations of this hydrocarbon (diisopropenyl) are the Br. patent 14,281 of 1910, and the French patent 417,768 (See the India-Rubber Jour., Feb. 4, 1911, p. 14, and Gummi Ztg., Feb. 10, 1911, p. 702, respectively), to the Badische Anilin & Sodafabrik, according to which the hydrocarbon is polymerised by heating, either alone or with the addition of such indifferent agents as water, a solution of common salt, or alcoholic caustic potash. After the polymerisation any unchanged hydrocarbon is distilled off with steam. The product is a white elastic substance, soluble in benzene, from which it is precipitated, unchanged, by alcohol, and it possesses the typical properties of caoutchouc.

Closely related to isoprene and to diisopropenyl, being in fact the mother substance of them, is erythrene, or divinyl, the 1.3-butadien, $CH_2:CH.CH:CH_2$. British patent 15,254 of 1909 (Gummi Ztg., Nov. 18, 1910, p. 261) to the Farbenfabriken vorm. Fr. Bayer & Co. of Elberfeld describes the polymerisation of this hydrocarbon to caoutchouc, the conversion being effected by heating under pressure either alone or with the ad-

dition of a reagent which assists in the polymerisation. Lebedeff has also studied this hydrocarbon and its caoutchouc polymer, the polymerisation having been effected in a similar manner, by heating at 150° in a sealed tube for several days. The polymerisation of this hydrocarbon is also briefly referred to in Chemiker Ztg., Feb. 7, 1911, p. 63, and it is here observed that the polymerisation takes place much more readily with this hydrocarbon than with isoprene.

Another hydrocarbon belonging to the same group as the preceding, and closely related to isoprene (beta-methyldivinyl) is piperylene or the alpha-methyldivinyl, $CH_3.CH:CH.CH:CH_2$. Thiele (Annalen der Chemie, 319 (1901), p. 227, has found that this hydrocarbon also, after several months standing in the dark, gives "a very small amount of a rubber-like (gummiartigen) substance, probably a polymerisation product." Most of the hydrocarbon in this experiment, however, remained with its boiling point unchanged.

The intimate relation to each other of the four hydrocarbons which have been described, and from which synthetic caoutchouc has been obtained, will be much clearer from a comparison of their structural formulae,—

CH_2	CH_2	$CH\text{-}CH_3$	CH_2
‖	‖	‖	‖
$C\text{-}H$	$C\text{-}CH_3$	$C\text{-}H$	$C\text{-}CH_3$
|	|	|	|
$C\text{-}H$	$C\text{-}H$	$C\text{-}H$	$C\text{-}CH_3$
‖	‖	‖	‖
CH_2	CH_2	CH_2	CH_2
Erythrene, divinyl, or 1.3-butadien.	Isoprene, 2-methyldivinyl, or 2-methyl-1.3-butadien.	Piperylene, 1-methyldivinyl, or 1-methyl-1.3-butadien.	Diisopropenyl, 2.3-dimethyl-divinyl, or 2.3-dimethyl-1.3-butadien.

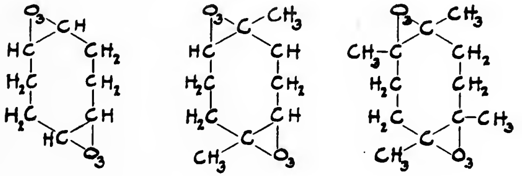
It will be seen that all four of these hydrocarbons belong to the divinyl series, containing the following common nucleus, C:C.C:C, and having respectively the empirical formulae C_4H_6, C_5H_8, C_5H_8, and C_6H_{10}. It is known that the caoutchouc from isoprene has the same percentage composition, and hence empirical formula, as natural caoutchouc, viz.: $(C_{10}H_{16})_n$. It should follow, since the formation of synthetic caoutchouc is by a polymerisation reaction, that the caoutchoucs from erythrene, piperylene, and diisopropenyl should also have the same empirical formulae as the hydrocarbons from which derived, or $(C_8H_{12})_n$, $(C_{10}H_{16})_n$, and $(C_{12}H_{20})_n$, respectively. Such formulae are also indicated by the ozonides referred to below.

A valuable contribution to the literature on the subject of

these diethylenic hydrocarbons (containing the nucleus C:C.C:C) is an article by Lebedeff dealing with their autopolymerisation found in the Journal of the Russian Physical-Chemical Society, 1910, Vol. 42, No. 6, p. 949. According to this article,—

"The polymerisation of these hydrocarbons takes place in such a typical manner that it may be considered a general characteristic of the whole group. The rapidity of the process, sometimes exceedingly slow at normal temperatures, increases very rapidly with rising temperature."

The polymerisation of the three hydrocarbons, erythrene, isoprene, and diisopropenyl was investigated in detail by Lebedeff, a caoutchouc polymer being obtained from each. The polymerisation was effected by heating in a sealed tube at 150°, the process requiring 6 to 7 days for its completion in the case of erythrene, and 8 to 10 days in the case of isoprene and diisopropenyl. Ozonides were formed from each of these polymers, the ozonides derived from the erythrene, isoprene and diisopropenyl polymers having the formulae $C_8H_{12}O_6$, $C_{10}H_{16}O_6$, and $C_{12}H_{20}O_6$, and yielding on decomposition with water succinic aldehyde, laevulinic aldehyde, and acetonylaceton respectively. To these ozonides, therefore, the following structural formulae were assigned,—



I. II. III.

The ozonide reactions of caoutchouc are particularly valuable because of the light they throw on the constitution of the caoutchouc molecule.

Two theories as to the constitution of this molecule have thus far been proposed. In view of the importance of the subject to which they relate it is desirable to examine these theories in detail. The first is the cyclooctadiene theory of Harries; the other is that proposed as an alternative by Pickles before the British Association last year. The former theory is given is two articles appearing in No. 36 of the Gummi Ztg., March, 1910, and Chemiker Ztg., 1910, March 26, p. 815, and translated

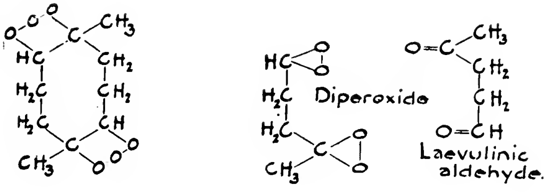
into the India-Rubber Journals of June 13, 1910, p. 772, and May 16, 1910, p. 630, respectively. The following is excerpted from the first of these articles,—

"As I will subsequently show, rubber is to be regarded as a polymerisation product of a hydrocarbon ($C_{10}H_{16}$) with a ring-like arrangement of eight carbon atoms. It might be assumed that by suitably strong depolymerisation treatment it would be possible to reduce the rubber to such a hydrocarbon. I have found that depolymerisation can, in fact, be effected, especially by long boiling of the rubber in toluol or xylol. However, the actual product which should be first produced, according to my theory, is not obtained, probably on account of its instability, but in its place allied compounds, such as dipentene and other hydrocarbons resembling turpentine. The fact, however, that rubber is depolymerised by protracted boiling in solvents of high boiling points is of importance for the question of the determination of its constitution. Regarding its molecular weight we know nothing definite; the experiments undertaken lately by Henrichsen cannot be regarded as decisive."

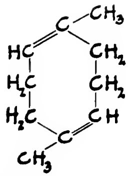
Caoutchouc is a hydrocarbon of the empirical formula $C_{10}H_{16}$; it is optically inactive, and has therefore no asymmetrical carbon atom. By bromination it takes up four atoms of bromine and accordingly possesses two ethylene linkings. Dissolved in choloroform and treated with ozone two molecules of ozone are added; and being readily soluble the formula of this so-called diozonide can be determined; it is $C_{10}H_{16}O_6$. At the same time the ozone treatment causes a depolymerisation of the high rubber molecule. On boiling this diozonide with water it decomposes into laevulinic aldehyde, laevulinic acid, and a crystalline body which I have named laevulinic aldehyde diperoxide.

$$C_{10}H_{16}O_3 = CH_3.CO\ .CH_2.CH_2.CHO$$
$$CH_3.CO\ .CH_2.CH_2.COOH$$
$$\text{and } CH_3.CO_2.CH_2.CH_2.CHO_2$$

"From this it would appear that caoutchouc ozonide must contain an eight carbon ring, for the ozone is situated at the ethylene linkings, and in splitting up, division of the molecule occurs at the positions where the ozone has entered, with the formation of compounds, aldehydes, or acids, containing oxygen. We come then to the following graphic formulae:—

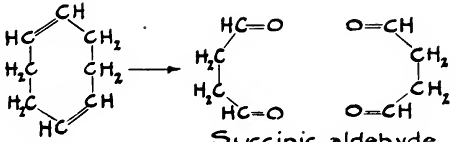


and the hydrocarbon which forms the basis of the caoutchouc molecule, and by the polymerisation of which the same is produced:—



1:5-dimethylcyclooctadiene (1:5)

Before I showed that in all probability the eight carbon ring occurs in caoutchouc, this carbon combination had not been discovered in nature. Shortly afterwards Willstaetter found an alkaloid in the root of the pomegranate, having likewise an eight carbon ring combination, and eventually he built up therefrom the lower homologue, which forms the basis of rubber chemistry. From this hydrocarbon, cyclo-octadiene, I have proved that the two ethylene linkings are situated in 1:5 position as caoutchouc, for it yields in the splitting up with ozone, succinic aldehyde.



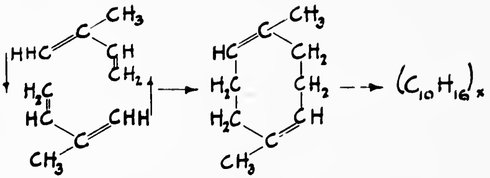
Succinic aldehyde.

On heating to 70°C. this cyclo-octadiene is polymerised, and under special conditions I obtained therefrom a product extraordinarily similar to rubber. * * *

All attempts to extract the two molecules of ozone from caoutchouc by suitable reduction, and even to regenerate the hydrocarbon, have hitherto failed; its synthesis also has not been accomplished."

Again in the India-Rubber Journal of May 16, 1910, in discussing the formation of caoutchouc from isoprene,—

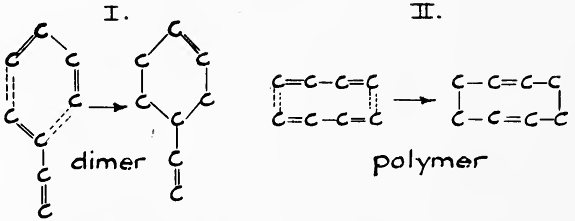
"In seeking to discover how the reaction occurs in the polymerisation, the conclusion is reached that isoprene first changes into dimethylcyclooctadiene, with condensation at the carbon atoms in 1:4 position, as in all addition reactions, results from bodies with conjugated double linkings.



"The condensation must take place in this way because on oxidation with ozone laevulinic aldehyde is formed."

A conclusion similar to that reached by Harries is also reached by Lebedeff in his article above referred to. This article, however, discusses the polymerisation of the whole class of diethylenic (C:C.C:C) hydrocarbons, and from a broader aspect. A further discussion of this article bearing both directly and indirectly on the constitution of rubber will therefore be given. Quoting further from this article,—

"A closer examination of the products of polymerisation, which consist of dimers and polymers of the diethylenic hydrocarbons, shows that we have to do with two parallel processes:



"The first process leads to the formation of a six-membered ring with two double bonds, one in the ring, and the

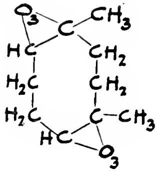
other in the side chain. The second process leads to the formation of an eight-membered ring with two double bonds, closely related to

$$\left\{\begin{array}{l} -C-C=C-C \\ \;\;| \qquad\qquad\quad | \\ \;\;C-C=C-C \end{array}\right\}_x$$

From a consideration of the above proposed system it is obvious that a symmetrically arranged molecule can give rise to only one dimer with a six-membered ring. Such are divinyl and diisopropenyl. As a matter of fact, the dimers of divinyl and diisopropenyl consist of only one hydrocarbon. * * * An unsymmetrically arranged molecule may give rise to four dimers. In the case of isoprene two such dimers have been observed; the other two it has not been possible to identify. Those observed are dipentene and a hydrocarbon of boiling point 160-161° at 760 mm. * * *''

Lebedeff's experiments with erythene, isoprene and diisopropenyl and the ozonides obtained from them have already been referred to above. In discussing the ozonide from the isoprene polymer it is further observed,—

''The system of polymerisation proposed by me foresees the possibility of the formation of another isomeric ozonide



''Whether this isomer is formed is not yet clear.''

The non-existence, or the existence if at all, only in very small amounts, of such an isomeric ozonide would seem to indicate strongly that the unsymmetrical position of the methyl group in the isoprene molecule exerts a marked influence on its polymerisation. This lack of symmetry in hydrocarbons such as isoprene is indeed mentioned by Lebedeff as one of the factors influencing the polymerisation reactions of these hydrocarbons. It was found by him that the polymerisation by light is much slower in the case of isoprene than in the case of diisopropenyl. It is also interesting to observe in this con-

nection that divinyl has similarly been found to polymerise much more readily than isoprene (Chem. Ztg., above).

The conditions under which the polymerisation is effected are also mentioned by Lebedeff as influencing the polymerisation reaction. Low temperatures favor the formation of the polymer; sunlight seems to act in the same way. Increasing the temperature facilitates the reaction but favors the formation of a larger amount of dimer. The reactions appear to be equilibrium reactions but the equilibrium exhibits some peculiar characteristics.

The dimer and polymer are not mutually convertible the one into the other, and the relative amounts of dimer and polymer remain practically constant during the reaction if the temperature and other conditions of reaction remain constant. This result is to be expected from the nature of the two products. The conversion of the monomer into the dimer and polymer will also go to completion if allowed to do so, all the monomer disappearing. It is interesting to observe that the amount of dimer formed from isoprene was larger than from the symmetrical diisopropenyl.

Returning now again to the subject of the constitution of rubber, and taking it up from another direction, is is desired to call attention to the following conclusions which were drawn by Pickles after a thorough discussion and consideration of the products of the pyrogenic decomposition of rubber (Address before the British Assn., 1906, Reports, p. 247).

"(1) The rubber hydrocarbon is closely related to the terpenes, and any formula expressing its constitution must also be explanatory of the easy transition of this hydrocarbon into isoprene and dipentene.

"(2) The existence of the complex $C—\underset{CH_3}{C}—C—C$ must be assumed in the rubber molecule, as it occurs in all the examined decomposition products.

"(3) Isoprene and dipentene do not occur in the rubber molecule as such, but are produced by the disruption of a larger or more physically complex molecule at a high temperature, for, as Fisher and Harries have shown, if the distillation is conducted at as low a temperature as possible, these compounds are not produced in any considerable quantity."

Turning now to the theory which Pickles has suggested as an alternative to that of Harries, and which was published for the first time last year, the following is found,—

"Since Harries has shown that laevulinic aldehyde, laevulinic aldehyde peroxide, and laevulinic acid are the only oxi-

dation products of caoutchouc, the polymerisation of isoprene into rubber must be accompanied by a rearrangement of the double bonds,

$$CH_2:CMe.CH:CH_2 \longrightarrow .CH_2.CMe:CH.CH_2.$$

as on on other assumption is the formation of laevulinic aldehyde possible.

"As is well known, this re-arrangement takes place in many cases where subtsances possessing conjugated ethylenic linkings enter into chemical combination. It is suggested that these unsaturated C_5H_8 nuclei unite to form long chains of the structure:

$$CH_2.CMe:CH.CH_2.CH_2.CMe:CH.CH_2.CH_2.CMe:CH.CH_2.$$

and that the number of C_5H_8 complexes may vary in different kinds of rubber, the difference in properties being probably due to this variation in the number of complexes contained. The oxidation results require that the two ends of the chain should be linked together, which, of course, leads to the formation of a ring, but it is proposed that in each rubber molecule there is only one such ring. Rubber probably contains at least eight C_5H_8 complexes connected as above indicated.

"This suggestion is put forward as an alternative to Professor Harries' **cyclo**octadiene formula, which is to a certain extent unsatisfactory, as its arrangement demands the employment of vague and unnecessary conceptions of polymerisation.

* * *

"For this view of the composition of caoutchouc the assumption is necessary that the polymerisation is either purely physical or that the connection between the individual chemical molecules is of so loose a nature as to allow the ozone first to depolymerise the aggregate before it attaches itself to the individual molecules. The necessity for this rather vague and unsatisfactory assumption results from the acceptance of the dimethyl**cyclo**octadiene formula, for if the polymerisation were chemical in character, the polymeride formed would be relatively less unsaturated than the $C_{10}H_{16}$ nucleus. This, however, is not the case, for rubber contains one ethylenic linkage for every C_5H_8 complex. Moreover, there are several facts which are not satisfactorily explained by Harries' formula. Since ozone effects depolymerisation, it is to be expected that other substances which tend to saturate the compound would likewise have a similar primary influence. Bromine should, therefore, first depolymerise the colloidal molecule, and then form simple molecules having the formula $C_{10}H_{16}Br_4$. But the properties of the bromoderivative of caoutchouc, and its gen-

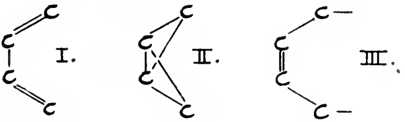
eral behavior indicate a composition probably as complex as that of caoutchouc itself."

Pickles further observes that nitrous gases act in a manner similar to bromine, giving a derivative of relatively high molecular weight. Reference is also made by him to Berthelot's experiments in which on reducing caoutchouc by heating to a high temperature with hydriodic acid hydrocarbons of the paraffine series were obtained of a boiling point much higher than would correspond to bodies of the formula $C_{10}H_{20}$.

The above theory suggested by Pickles is not as a whole entirely satisfactory. It is hard to conceive of a molecule with a single forty carbon atom ring. It is difficult to explain how such a forty membered ring, once formed, could react by further polymerisation or depolymerisation. Finally the existence of a small number of bonds or valencies of a much more reactive nature than the rest is not explained by such a theory. The existence of such bonds in rubber is strongly indicated by its vulcanisation reaction. Weber (Chemistry of India-Rubber) states that as little as 2 to 2.5% of sulfur is sufficient to effect complete vulcanisation and that the resulting vulcanised rubber possesses the highest degree of elasticity and distensibility combined with the highest degree of tensile strength. Rubber possessing a higher coefficient of vulcanisation sometimes shows higher tensile strength, but at the expense of the other physical constants.

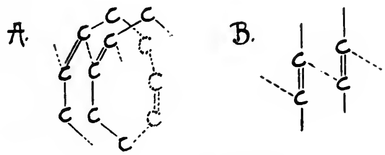
In summarising the foregoing facts and theories it would seem that any acceptable theory of the constitution of the caoutchouc molecule must not be inconsistent with the following observed facts,—Caoutchouc yields on treatment with ozone a product of depolymerisation and addition, caoutchouc ozonide; it gives on treatment with bromine a product of addition but not of complete depolymerisation, the so-called tetrabromide; it gives on depolymerisation by boiling in solvents of high boiling point, not the cyclooctadiene, but the more stable six-membered-ring terpenes, such as dipentene; on destructive distillation it gives a series of products of widely varying complexity from isoprene through dipentene to the more complex and higher boiling products which result particularly from vacuum distillation; it is converted into hydrocarbons of the paraffine series by hydrogenation; it may be formed by the polymerisation of isoprene and similar hydrocarbons, but not from dipentene, and it may itself be converted from a lower to a higher state of polymerisation and vice versa; and finally it may be completely vulcanised by a very small amount of sulfur.

A valuable suggestion bearing indirectly on the present subject is found in a communication by Wechsler in Chem. News, Vol. 100 (1910), p. 279. In discussing the reactions of bodies containing in their molecule the group —C=C—C=C— Wechsler suggests that **if we write the carbon atoms more according to their relative positions in space**, as in (I), then, **if the double bonds attract each other**, we have (II), in which the end atoms are much more open to attack than the middle ones.



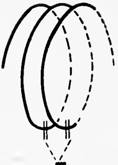
From the formula (II) suggested by Wechsler it is but a step to formula (III), which has been hereinbefore referred to.

If we apply the above suggestion to the long chain proposed by Pickles, and **write the carbon atoms more according to their relative positions in space**, we would not expect to obtain a single ring of at least forty carbon atoms, but we would expect this long ring to double back upon itself at about the sixth carbon atom. Then **if the double bonds**, which recur regularly at the fourth and eighth carbon atoms, **attract each other**, and are able mutually to satisfy each other, they might be expected to join together and give a molecule with a configuration similar to that of a helix or spiral spring,—the contiguous alternative double bonds being thus joined to, and satisfied by, each other. A fragment of such a molecule might be represented graphically as in (A) with the double bonds joined together as in (B).



Such a spiral or helical molecule would be closely related to the cyclooctadiene ring, as will be apparent from the following diagrams. From these it will be seen that the alternative

double bonds are in practically the same relative positions whether we have a series of cyclooctadiene rings (B) or a spiral (A). An explanation of the eight membered ring, or a structure closely related to it, is thus made possible by the modifying action of these contiguous alternative double bonds.


A


B

Such a spiral molecule could form the tetrabromide by addition of bromine at each double bond without depolymerisation; it could break completely at each alternative double bond with rearrangement of the ring to give the stable six-carbon-ring terpenes; it could break at each alternative double bond in a different manner to give the ozonide; on pyrogenic decomposition by heat this molecule might break at any of its double bonds to give products of varying complexity, but all having the empirical formula $(C_5H_8)x$; by hydrogenation such a molecule might be expected to give a saturated hydrocarbon of the paraffine series. It is proposed that the bonds at the ends of such a molecule are free, or relatively free, so that this molecule can further react to give a more highly polymerised product; and it is further proposed that by the saturation of these bonds by sulfur vulcanisation is effected.

This theory requires that the spiral molecule have its alternative double bonds joined together and saturated by each other, but joined in such a manner that upon treatment with suitably strong reagents addition may take place much as if the double bonds still exist in a modified and less reactive form.

The spiral or helical theory above suggested has not, to the knowledge of the present writer, heretofore been published. It is with not a little hesitation that it is offered at this time. But if it shall aid even a little in the ultimate solution of the nature of the rubber molecule its object will have been accomplished.

ANTHRACITE PRODUCER GAS FOR FUEL PURPOSES.

By M. S. FLINN, M. E.*

In the manufacture of many products heating operations are involved which combine to make up a considerable part of their ultimate cost, and for the reason that competition is only met profitably when operating and manufacturing factors are reduced to the lowest point, economy is and undoubtedly will continue to be the watchword of successful industry. Until rather recently little or no attention was directed towards effectually cutting down the expense incident to forging, hardening, tempering, japanning and such operations. It is also of considerable interest to know that never in the history of manufacturing endeavor have the demands for quality and strength of material been so strict as at the present time—the advent of the automobile, to a great extent, being responsible for this.

In the heat treatment of steel great progress has been made in ascertaining temperature conditions which will produce definite effects in regard to its structure. It has become the practice in many factories to submit the steel parts to various heating operations in order to make them physically able to withstand the ultimate wear and tear they will undergo when assembled and have become the working parts of a greater mechanism.

The several fuels with which the manufacturer generally comes in contact, together with their respective heating values, are:—

Wood	6,000 B. T. U. per 1 pound.
Bituminous coal	13,000 B. T. U. per 1 pound.
Anthracite coal	12,500 B. T. U. per 1 pound.
Fuel oil	140,000 B. T. U. per gallon.
Gasoline and naphtha ...	125,000 B. T. U. per gallon.
Natural gas	1,000 B. T. U. per cu. ft.
Carbureted water gas ...	600 B. T. U. per cu. ft.
Coal gas	625 B. T. U. per cu. ft.
Water gas	300 B. T. U. per cu. ft.
Raw bituminous producer gas (hot)	250 B. T. U. per cu. ft.
Anthracite producer gas (cold)	145 B. T. U. per cu. ft.

The heat values given are necessarily approximate on account of the variable nature of the fuels, but they indi-

*Class of 1904. Secretary and Treasurer, Flinn & Dreffein Co., Engineers and Manufacturers, Chicago.

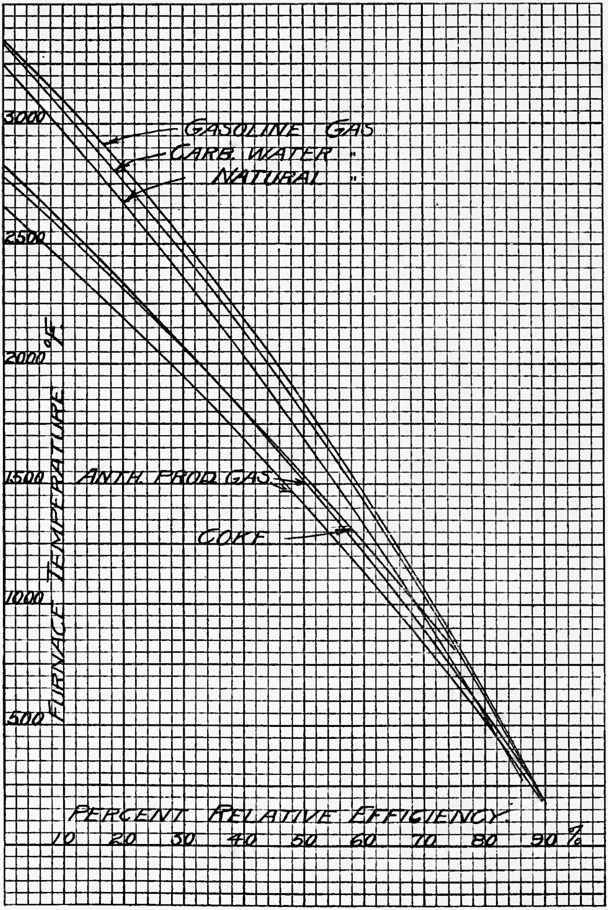


Fig. 1. Curves showing Relative Efficiency of Several Fuels at Various Furnace Temperatures.

cate a fair average. This is a formidable list from which one has to choose; however, they may be classified as 1st, Solid; 2nd, Liquid; 3rd, Gas. There exists a definite relation between each and every one of them from which comparative costs can be readily established. The relations in turn are affected by the nature of heating work they are to perform.

Heating operations may be divided into three classes: 1st, Low temperature; 2nd, Medium temperature, and 3rd, High temperature. For low temperature operations the relations between the various fuels are almost proportional to their respective B. T. U.; however, for higher temperatures this is not the case. In other words since natural gas has a heat value of about 1,000 B. T. U. per cu. ft. and anthracite producer gas 150 B. T. U. per cu. ft. it would seem that 6½ cu. ft. of producer gas will do the equivalent heating work of 1 cu. ft. of natural gas, regardless of the temperature demanded by the operation. For low temperatures this holds very nearly true, but at high temperatures a greater quantity of producer gas is required to equal a cubic foot of natural gas. The reason for this is that the flame temperature of natural gas is higher than that of producer gas, being about 3,700 deg. F. and 2,700 deg. F. respectively, under ordinary conditions, where air is used to support combustion.

The flame temperature resulting from combustion depends upon the heat evolved by the chemical reactions and the specific heat of the products of combustion. Numerically, the flame temperature equals the heat units, evolved by the fuel, divided by the product of the combustion gases and their specific heat. It is the ratio then of the B. T. U. of a unit of fuel to the products of combustion times its specific heat, and as the excess air for combustion is increased, so is the flame temperature decreased. Again, in a fuel containing elements not assisting combustion the same result occurs—for instance, a gas carrying proportions of carbon dioxide and nitrogen. Consideration of these facts must be taken in comparing fuels for various heating operations.

The curves in Fig. 1 show in per cent the available heat that can be obtained from the various fuels when properly burned under practical conditions. It will be observed that the several curves converge as the temperatures of the furnace operations decrease. In other words, for such work as japanning, baking and the like, where a temperature in the neighborhood of 500 deg. Fah. is necessary, a B. T. U. in one fuel will go very nearly as far as a B. T. U. in another. As the temperature demands increase for hardening, tempering, an-

nealing, and the like, the efficiency of the poorer fuels—as, for instance, producer gas—falls off so that for an operation demanding 2,000 deg. Fah. the available heat in producer gas is about 28% as compared with 44% in carbureted water gas. Therefore, the ratio between 44 and 28 (or 1.57 B. T. U.), is necessary in producer gas to produce the same heating effect as 1 B. T. U. in the carbureted water gas.

The use of solid fuel in connection with furnaces is rapidly being displaced by the adoption of gas. The latter permits flexibility of operation unapproached by solid fuel, for the reason that by the simple manipulation of valves higher or

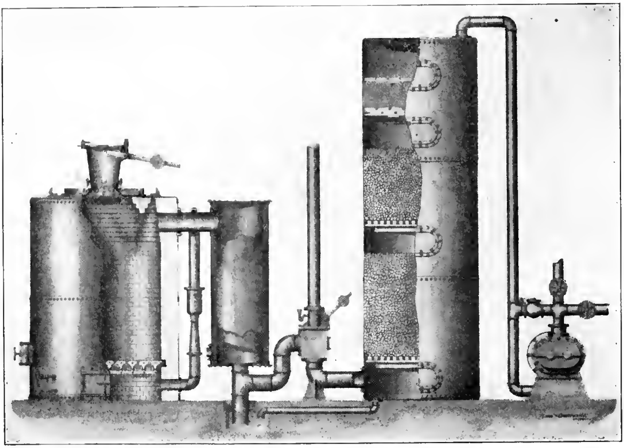


Fig. 2. Extension View of Anthracite Producer Gas Plant for Heating Purposes.

lower temperatures can be obtained. Very nearly theoretical mixtures of gas and air can be used, thus effecting high combustion efficiencies, whereas with solid fuels large excess of air is required. Many heating ovens are provided with thermostatic devices which automatically maintain the desired temperatures.

The introduction of producer gas for heating operations invites a consideration of this fuel in regard to its economy as compared with other fuels used in existing practice. The following is a description of the producer gas equipment, manufactured by Flinn & Dreffein Co., Chicago, for use in connec-

tion with industrial heating operations. Referring to the extension view shown in Fig. 2, from left to right the apparatus consists principally of, 1st, GENERATOR; 2nd, ECONOMIZER; 3rd, SCRUBBER, and 4th, EXHAUSTER. Coal is converted into gas in the generator. Gas leaving the

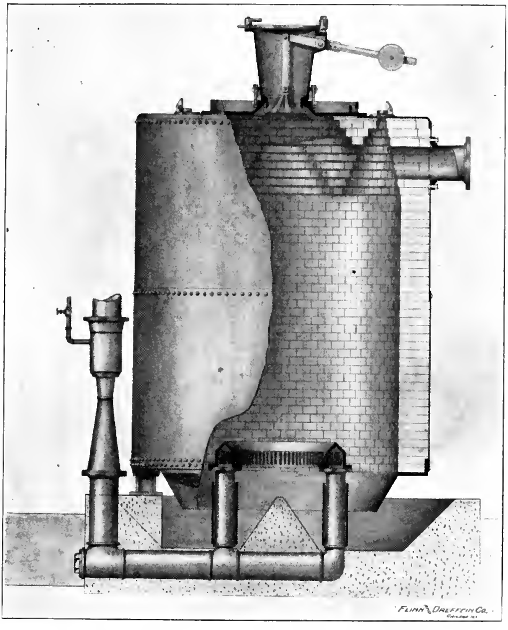


Fig. 3. Sectional Elevation of Anthracite Water Sealed Generator.

generator passes through the economizer where it gives up most of its heat, then through the scrubber where the soot, tar, and other impurities are removed, and lastly compressed by the exhauster and delivered to the gas mains.

Producer gas is made from the cheaper grades of anthracite coal, such as No. 1 buckwheat and pea sizes. The gas making process takes place in the generator, where a fuel column about 30″ deep, in the course of combustion, rests on a layer of ash about 8″ deep, both being supported by the shak-

ing grate. The ash, of course, is inert and merely acts as an insulation for the grate. Air, previously heated in the economizer and carrying with it steam, is supplied to the fuel column from underneath the grate. When the air and steam enter and come in contact with the hot coal (carbon), combustion takes place by the oxygen of the air combining with the carbon.

Fig. 4. Small Producer Gas Plant for Supplying Gas to Soldering and Japanning Ovens in a Lantern Factory.

In the presence of hot carbon, oxygen has a greater affinity for carbon than for hydrogen; so, as the steam comes in contact with the hot fuel it breaks up, the hydrogen passing up as a gas and the oxygen supporting the combustion of more carbon. At this stage three distinct gases are liberated: 1st, Carbon dioxide (CO_2), formed by the union of carbon and oxygen and representing products of complete combustion; 2nd, Hydrogen

(H) liberated from the steam; 3rd, Nitrogen (N) carried in with the air. The latter, being an inert gas, neither assists nor interferes with the reactions.

These three gases continue upwards through the hot fuel column. The hydrogen and nitrogen are permanent fixtures in the ultimate producer gas, but the carbon dioxide is acted upon further. In the presence of hot carbon, carbon dioxide

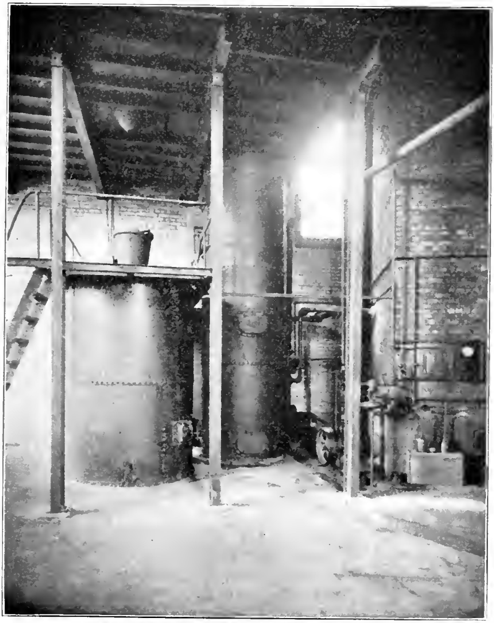


Fig. 5. Small Producer Gas Plant showing Generator, Economizer and Scrubber. Coal is Stored in Bunkers Above Plant.

picks up another atom of carbon forming carbon monoxide (CO), the reaction expressed chemically being $CO_2 + C = 2CO$. Carbon monoxide is a combustible gas and forms a large proportion of producer gas. This completes the chemical reactions which result in producer gas, although an additional component is methane or marsh gas (CH_4) which is present in small

quantities. This, however, is driven off from the coal by the heat in the generator.

If air only were used in this process a lean gas would result, as there would be no hydrogen, and the proportion of nitrogen (inert gas) would be increased. Aside from this, excessively high temperatures would result in the generator, producing clinkers and other objectionable results. This is avoided by the use of a quantity of steam which is carried in by the air and increases the quality of the gas by the addition of hydrogen, at the same time lowering the temperature in the generator.

The hot gas leaving the generator passes slowly downward through the inner chamber of the economizer, around which is an annular space up which air for supporting combustion in the generator passes. The air, passing upward, absorbs the heat from the inner chamber and is conveyed from the upper part of the economizer underneath the grate by means of the pipe shown in the illustration. In this way the energy, which passes off in the form of sensible heat in the gas leaving the generator, is utilized and increases the efficiency of the gas making process.

The supply of air to the generator and the flow of gas through the plant is produced by the suction of a positive rotary exhauster connected to the scrubber. The exhauster, normally, places the gas plant under suction so that when the pokeholes in top of generator are open there will be an inflow of air. To offset this suction, a positive supply of steam is used for saturating the air for generator. Steam is introduced by means of a steam blower such as is frequently used for forcing draft under boilers; by means of this device the suction, caused by the exhauster, is neutralized and atmospheric pressure can be maintained in the top of generator at all times. This is of great advantage, for the reason that attention may be given to the fires without inflow of air or outflow of gas.

Soot, tar, and other impurities are removed from the gas in the scrubber, which consists of a steel cylindrical tank, high in proportion to its diameter. A coke column, supported by trays, extends to within about 5 feet of the top. Above the upper surface of the coke are located water sprinklers, and over the sprinklers between two trays is a layer of excelsior. The gas, passing upward through the coke, intimately mixes with the water flowing downward; thus, the tarry particles adhere to the rough surfaces of the coke and are carried away

by the water. The water mechanically mixed with the gas is removed by the excelsior. Between the economizer and scrubber is a 3-way water sealed valve, so designed that it is impossible for both the vent to atmosphere and the inlet to scrubber to be open at the same time. The valve, being water sealed in both positions, insure tightness.

The gas is drawn from the plant, compressed, and delivered to the gas mains by means of a positive rotary exhauster.

Fig. 6. General View of Large Water Sealed Producer Gas Plant Supplying Gas to Cold Rolled Steel Annealing Furnaces, Sherardizing Kilns and Japanning Ovens.

Several methods are employed to maintain a constant pressure in the gas mains, the usual manner being, where steam is available, to drive the exhauster by a steam engine. A diaphragm pressure regulator controls the speed of the engine so only that amount of gas is delivered as is required, the diaphragm being set to maintain the desired pressure in the mains. When a motor is used, there is a pipe connection leading from the delivery side back to the suction side of the exhauster. In this pipe connection is placed a back pressure valve which is adjusted to open at the pressure to be carried in the gas mains. The speed

of the exhauster is usually constant and equal to the maximum demands. By this arrangement there is always circulating about the exhauster through the relief valve a quantity of gas. A drawback to this method is that the power required to drive the exhauster is excessive. In the larger installations a variable speed motor is frequently used so that the attendant to the plant can keep the speed of exhauster, within reasonable limits, proportional to the load.

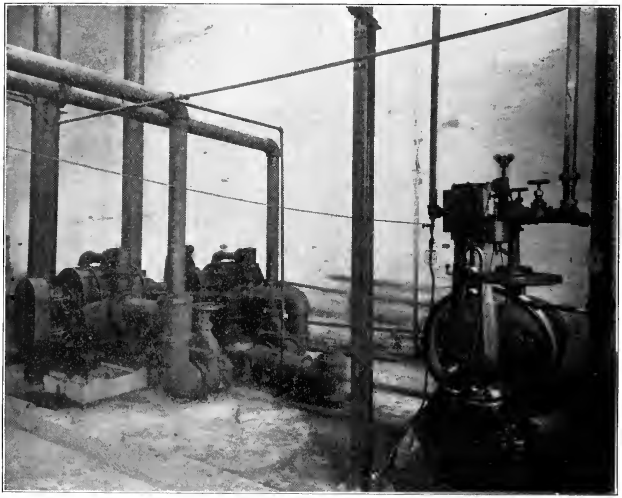


Fig. 7. Exhauster Equipment of a Large Producer Gas Plant.

In plants of large capacity a water sealed generator is used instead of the shaking grate type. It differs only in the manner of supporting the fuel column to the extent that the shaking grate is dispensed with and the air and steam delivered to the fuel column by means of a tuyere. The object of this form of generator is to provide facilities for cleaning and removal of ash, for, in large diameters the shaking grate becomes too cumbersome.

City gas is the most generally used gas fuel, and has a heating value of about 600 B. T. U. per cu. ft. Pea and No. 1 Buck-

wheat anthracite coal contain 12,500 B. T. U. per pound. In a producer gas plant about 80% of the energy in the coal is made available in the gas, so that for every pound of coal gasified there are 10,000 B. T. U. delivered into the gas. Theoretically, then, 60 pounds of coal burned in the producer plant will generate the equivalent of 1,000 cu. ft. city gas. Taking into consideration, stand-by losses and the relative efficiencies in combustion of city and producer gas, practice shows that 80 pounds of coal is a reasonable figure for heating operations up to the requirements of hardening, tempering and annealing.

As an illustration of economy in use of producer gas: Assume a can making factory where city gas has been used for heating solder baths, soldering irons, and the various tools used in this manufacture, and where the gas consumption has been 780 M. cu. ft. per month at $1.00 per M.; an anthracite producer gas plant has been installed and the comparative costs are:—

City Gas.

780 M. cu. ft. @ $1.00 = ... $780.00

Producer Gas.

To displace 780 M. cu. ft. city gas required 62,400 pounds or 31.2 tons of No. 1 Buckwheat coal.

Cost of Producer Gas per Month.

Coal, 31.2 tons, @ $3.15 = ...	$ 98.28
Water for cleaning gas, 2 gallons per pound of coal, 124,800 gallons @ 10c per M.	12.48
Power for operating exhauster, 8 H. P., @ $3.00 per month	24.00
Steam, ½ pound per 1 pound coal, or 31,200 pounds, requiring 5,200 pounds, or 2.6 tons coal @ $3.15...	8.19
Labor, part of one man's time, @ $1.00 per-day.......	26.00
Interest, depreciation, maintenance, @ 12½% on $5,000 investment	52.08
Total cost producer gas per month................	$221.03

This shows a saving over city gas, therefore, approximating $559.00 per month, or $6,708.00 per year; and also that the equivalent of 1,000 cu. feet of city gas is made for about 28.4c.

THE POWER NECESSARY TO DRIVE AN AEROPLANE.

By SYDNEY V. JAMES.*

The problems to be met with in the design and development of the aeroplane are numerous and of widespread interest to technical men all over the world at the present time. There are thousands of experimenters working along the lines of aeroplane development and a great many ideas are being tried out in practice. Now that the possibilities of the aeroplane have been fairly well indicated by many successful flights, the interest of the engineering profession is being aroused, and a much more logical development of the numerous problems will be attained, together with the consequent shortening of the time required to reach the practical stage. It is with the hope of creating some interest in the aeroplane from the engineering point of view that the writer will present

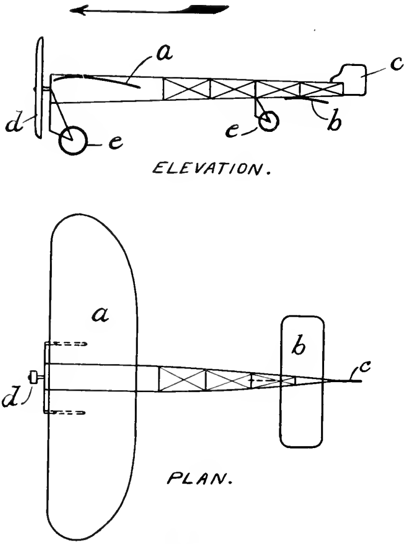


Fig. 1.

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the following general consideration of the more salient features of the problem of powering an aeroplane.

We shall select, for the sake of simplicity, an aeroplane of the monoplane type such as the Bleriot machine and let Fig. 1 represent a plan and side elevation of it as running horizontally in the direction of the arrow. Referring to the figure, "a" represents the main supporting surface, "b" the tail surface, "c" the rudder, "d" the propeller (which in this machine is a tractor, since it draws the aeroplane along), and "e" the wheel for running along the ground before the

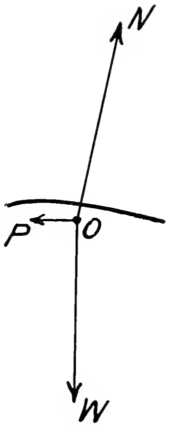

Fig. 2.

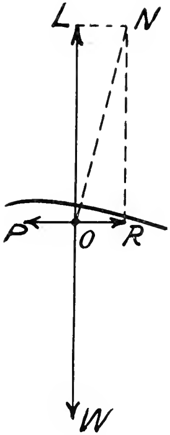

Fig. 3.

speed necessary to sustain the machine is attained. In order to study the forces acting on the aeroplane, let Fig. 2 represent the side view of the main surface, with 'O' the center of gravity of the machine. There will be three forces acting when in horizontal flight; ON the resultant reaction of the air pressure on the entire machine; OW the weight, acting, of course, vertically downward; and OP the pulling force exerted by the propeller. For the purpose of this discussion, the above forces are considered as concurrent. This is practically true for most successful aeroplanes.

In flight at a uniform speed, the system of forces is in equilibrium and it is convenient to replace ON by its components perpendicular to and parallel to the line of motion. This

is shown in Fig. 3 where OL is the component perpendicular to the line of flight, and OR is one parallel to the line of flight. The forces acting may be considered to be, then, the propeller force OP, the weight OW, the "lift" OL and the resistance to motion OR.

The force OR is opposed to forward motion and must therefore be balanced by OP. The lift OL must be balanced by OW, the weight of the entire outfit, including operator, fuel, etc. As a basis for supplying the proper amount of power, the value of the propelling force must be determined. We know it must be equal OR, hence the value of OR must be determined. The most logical way to do this at the present time is to make as close an estimate as possible of the resistance of each part of the machine, including the horizontal components of the air pressures on its surfaces. This may be done with a fair degree of approximation for any of the well known types, but the value thus obtained must be checked by comparison with values deduced from observations on real machines in actual flight.

Experiments have been made with an aeroplane having its propeller so mounted in the bearings that a calibrated spring would indicate the actual thrust during flight. The results obtained under various conditions with this kind of apparatus give us valuable data for future calculations.

There are other ways of finding the resistance by observation of machines, and the most obvious is to allow the aeroplane to glide with the engine shut off. Under these conditions the path of flight is no longer horizontal, for the machine approaches the earth at a small angle to the horizontal. In Fig. 4 this state of affairs is shown. The path of flight makes the angle θ with the horizontal and the size of this angle is determined by the resistance as compared with the weight of the aeroplane. This is true because the propelling force OR′ must be component of the weight in the direction of motion and the machine will adjust itself at such an angle that this force exactly equals the resistance OR. The component of the weight OW′ perpendicular to the line of flight balances the lifting force OL and the aeroplane glides at a uniform velocity at an angle θ with the horizontal.

Now the angle WOW′ is also equal to θ, and WW′÷WO equals sine θ. But WW′=R′O, hence R′O÷WO equals sine θ. Therefore if we measure the gliding angle and know the total weight of any given machine, the resistance in the line of flight becomes a matter of calculation and is equal to WO sine θ.

It is clear, after the above condition is realized, that in order to have horizontal flight under power, the propeller must supply a force equal to this resistance. An expression showing the relation between the thrust and the engine power will be necessary, therefore, to find the power. The Thrust Horse Power may be expressed by the equation:

$$\text{T.H.P.} = \frac{\text{TV}}{550}$$

where T = thrust or pull of propeller in pounds, V = velocity

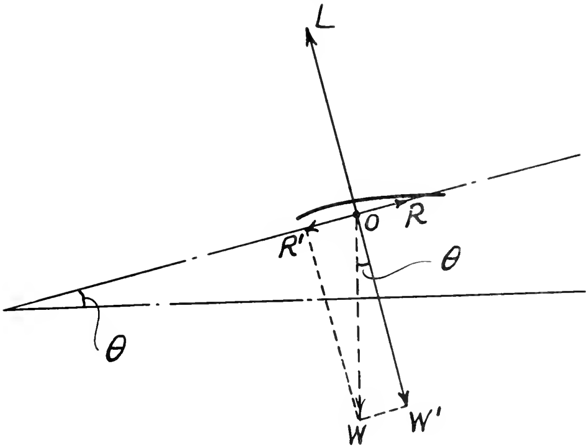

Fig. 4.

of flight in feet per second, and 550 converts the foot pounds of work per second of the numerator into horse power.

If the efficiency of propulsion be represented by e, then the Brake Horse Power of the engine itself will be

$$\text{B.H.P} = \frac{\text{TV}}{550\text{e}}$$

By examining the above equation, we see that everything else remaining constant, the B.H.P. varies directly as the thrust required, or in other words, if we have the power required to develop say 100 pounds thrust at the propeller at any given speed of translation through the air, we know that if a 200

pound thrust is required the power must be doubled. Hence, if we work out our data on the basis of 100 pounds thrust, we simply have to multiply the value for the power obtained from these figures by the ratio of the required thrust to 100 pounds.

Substituting in the formula above the value 100 pounds for T we have

$$B.H.P = \frac{100V}{550e},$$

hence for any given value of "V" a curve may be plotted with B.H.P. as abscissa, and efficiency "e" as ordinate. This has been done for a series of values of V ranging from 20 to 75 miles per hour, in steps of 5 miles, and the diagram shown in Fig. 5 drawn. This covers a range of propeller efficiency from 35% to 80% thereby including all present practice.

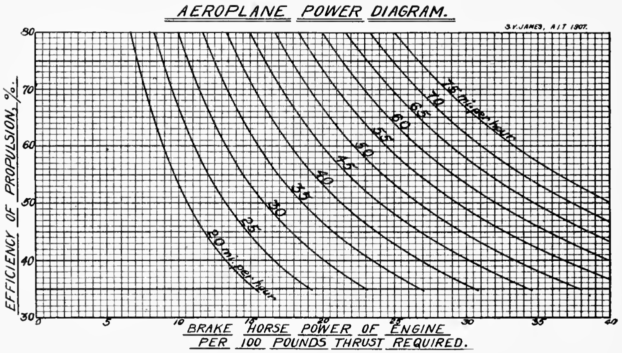

Fig. 5.

To illustrate the use of the above in figuring out the amount of power, let us take the case of a Wright aeroplane having the following characteristics: Normal speed 35 miles per hour or 51.3 feet per sec., gliding angle 8°, total weight about 1100 pounds. The thrust necessary for horizontal flight would be $T = 1100 \sin 8° = 1100 \times 0.139 = 153$ pounds. Therefore, assuming 60% efficiency

$$B.H.P. = \frac{153 \times 51.3}{0.60 \times 550} = 23.75$$

This result can be found by using the chart reading 15.5 B.H.P,

at the intersection of the 35-mile line with the 60% efficiency line and multiplying it by the ratio of 153 to 100 or $15.5 \times 1.53 = 23.7$ B.H.P.

The Wright engine has a full load capacity of 30 to 32 horse power, thus having a reserve power of about 25% which is called into play when ascending from the ground, or opposing a head wind.

A Bleriot XI machine, such as we used in Fig. 1 for example, has the following characteristics: Total weight 770 pounds, normal speed 50 miles per hour, or 73.34 feet per second, gliding slope of about 1 in 7.5, efficiency of propulsion 50%. Hence the thrust required will be $T = \frac{770}{7.5}$ or 102.6 pounds, and the

$$\text{B.H.P.} = \frac{102.6 \times 73.34}{0.50 \times 550} = 27.35$$

This result may also be obtained from the chart by reading 26.7 B.H.P. at 50% efficiency and 50 miles per hour, then multiplying by $102.6 \div 100$ or $1.026 \times 26.7 = 27.4$ B.H.P. as above. The Bleriot XI is furnished with a gnome motor which develops about 45 actual brake horse power, hence there is a reserve of about 40%.

The chart is useful in getting a rapid survey of the power problem, showing how much power will be necessary for horizontal flight, as it enables a person to pick out the value for any probable or desired set of conditions as to speed, efficiency and thrust or resistance. It also shows in a graphical way the value of high efficiency and the penalty for low efficiency of propulsion.

THE PLANNING AND ERECTION OF POWER PLANTS.

By E. J. HEINEN, M. E.*

In the design of a central station a broad scientific training, extensive experience and technical ability are required. Knowledge of the mechanical, electrical or civil subjects will not alone suffice, although all of these are called into play in the design of a successful central station. Soon after the introduction of alternating current machinery and long distance transmission lines, the three-phase induction motor secured a place in manufacturing industries which has brought about a standardization of power plant machinery, the results of which are noticeable in some of the larger plants of late years.

In the planning and designing of a power plant the preliminary is of the greatest importance, and many factors that affect the general results cannot be decided upon except through available data and much study—guided by past experience. The first step is the determination of the load curve which, in case there is no available data, involves a thorough study of local conditions. These load curves, with careful study of overload and reserve power, determine the capacity of the plant and proper size of units. The layout and arrangement of these largely depends upon the type of apparatus selected—the prime movers, generators, boilers, and auxiliary machinery. Unit system is very much to be favored in a design, because of its many advantages and few disadvantages, and consisting as it does of a number of separate plants of uniform equipment side by side. The piping in a unit system of installations usually cross connect all the units, thus permitting any one unit to be operated with boilers normally assigned to their own unit

The condensing system is usually of the independent type, although the use of this system is not always the best policy, for when large units are installed, and there are not too many joints and long runs of pipe, the interchangeable system may prove the more profitable. The endeavor to place the condenser close to the low pressure end of the prime mover, with no means provided for an atmospheric exhaust, makes it necessary to shut down the unit whenever repairs on the condenser are necessary.

The arrangement of the machinery should be such as to permit access for repairs; the passage ways should be ample

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to allow for parts of a machine to be placed out on the floor, which, in turn, should be designed to carry any load as may occur in such cases. The various machines should be so placed that the pipe lines will be short, and, wherever possible, bends should be provided to allow for expansion. If the dimensions of the site are fixed by circumstances, it may not be possible to obtain the most desirable arrangement of the equipment. The different advantages and disadvantages can best be determined by considering a number of alternative arrangements, consisting of various types of apparatus together with the layout of necessary piping. The final arrangement can only be decided upon after careful study and results of past experience.

The location of a power plant is often difficult to determine. It properly depends upon the source of power to be developed, but is often governed, in the case of a gas or steam plant, by conditions such as fuel, water, labor supply and disposal of waste. If a water power plant, the location must be accessible for building material and machinery, and yet located at a point to obtain the maximum hydraulic head.

Owing to the possibility of piping water from a distance, the water problem of a plant is considerably reduced. With such a supply it is advisable to provide storage tanks, or a reservoir close to the plant, to guard against interruptions such as a shut-off for repairs. If city water is the supply to a plant, it is a good plan to provide a tower tank for emergency cases. Such a layout has shown the possibility of operating a plant after the bursting of a city main and until repairs on same could be made. If the water must be purchased, it is advisable to develop its own supply. The quantity of water required depends upon whether surface or jet condensers are used; in the case of surface condensers, the water condensation may be used for boiler feed. It is almost impossible to obtain good water for boiler feeding and consequently the boilers require constant attention and must be cleaned at regular intervals. The modern method of dealing with feed water of this kind is to remove the scale forming substances before they reach the boiler. The installations of water softening plants for purifying boiler feed water are becoming more numerous and have proven their efficiency by reducing fuel consumption, expense of boiler cleaning and repairs.

The fuel supply and the question of handling the same is of the greatest importance, for the cost of fuel must include the expense of handling it between the cars and grates, and the dis-

posal of ashes. The expense of handling coal is reduced to a minimum by delivering it directly to the plant in cars or barges, and carting the ashes to a dump, since the coal required is about fifteen times the weight of the ashes. With increase in size of plants, the importance of a reserve supply of coal to guard against interruption of service becomes evident. Water transportation is closed in many localities for several months in the year, and railroads are subject to interruptions through wrecks, strikes or badly congested freight which make it impossible to tell how long a train will be on the road.

In localities where natural gas is available for fuel under boilers or in gas engines, a reserve is very seldom kept, but duplicate pipe lines are installed to insure against an interruption of service. Fuel oil has been used to advantage, being delivered to the plant by pipe lines, cars or boat. A storage tank provides for a supply between shipments, or any interruptions that may occur due to weather conditions and other causes. The fuel-storage plant should be located near the plant, if sufficient ground space is available. A fuel-storage plant such as bunker capacity over the boilers involves considerable investment in its equipment and maintenance, but is an insurance against interruption in fuel supply in case of a conveyor break down.

The design of the building and arrangement of the machinery often destroys the architectural features by the attempt to place the coal handling plant in the most conspicuous point in the layout, and thus possibly save a few dollars. This fact in some instances interferes to such an extent that it appears as if there was a coal handling plant with a power plant annex. It is often possible to design the coal handling plant to harmonize with the main building with but slight additional cost; however, this is usually offset by a reduction in the up-keep on the structure and equipment.

The layout of the plant and the types of apparatus selected for the generation of steam and electricity usually determine the design of the main building and the steel framing. The unit system of design for the mechanical installation permits the same system to be used in the design of the steel superstructure. In power plant design, however, it is the results attained from the complete machine which must be considered, and while a good architectural effect is to be desired, the efficiency of the plant cannot be sacrificed to gain it. For the interior finish of the walls, a light blue-colored pressed brick and an enameled tile wainscot four or six feet in height above the floor has

many advantages, since such a finish never requires renewal, and is easy to keep clean.

The cheapest form of illumination is obtained by large windows, large both in height and in width. Where exposed at any time to the direct rays of the sun, rough surface or translucent glass may be used, or wire glass, owing to its advantages as a fire retardent. Skylights furnish a very desirable means of supplying light, particularly for the operating floor. These may be located in every other bay, or the entire length of the bay, and can be glazed. For the purposes of ventilation a monitor is usually provided over both the operating and boiler rooms. In the operating room glazed sashes, opening on pivots, are usually provided. The monitor over the boiler room that houses the machinery for distributing the coal has glazed sashes on pivots in order to provide for illumination.

Roofing on some prominent plants consists of Spanish roll tile set on brook tile carried by T-irons and supported by the purlins. Reinforced concrete slabs are just as efficient as the brook tile, and with this construction a coat of mortar is not required on the lower surface to secure a uniform finish.

Platforms and walkways are often confined to fixed limits, and these should be considered in the general layout so as to avoid insufficient clearance and necessity of walking on pipes in order to reach valves. Gratings constructed of light material between channel iron stringers form a curb to prevent tools being kicked overboard accidentally, for a tool disappearing over the edge at an inopportune time or place may cause serious damage.

Concrete slabs and arches for flooring have replaced the porous or hard-clay hollow tile. The floor finish can be colored by mixing in lamp black so that oil drippings will not be so conspicuous; a hard finished surface of this kind is also a prevention of dust—a very desirable feature in operating rooms. The sanitary curve should be used at all corners, and all pipes passing through the floor should be surrounded by suitable thimbles with about four inches clearance above floor level to protect the pipe covering from wash water. Drainage slopes should also be arranged with floor drains, so that as far as possible water will run off.

Main passageways should be of ample width and should not be less than five feet. Stairs should be as straight as possible in order to carry pipes or other long pieces from place to place. In places where space is limited, ladders may be used to advantage; however, stairs of steep incline with treads of special construction are often used to advantage.

Main doorways to the boiler and operating room should be of sufficient size to permit running railroad cars into the building where they may be unloaded by the crane.

The foundation is the most important portion of the power plant, and where rock or other solid bottom can be reached in a reasonable distance, the foundation should be carried down to it. In most cases when the plant is located on made or filled land, isolated piers are liable to unequal settlement; in addition, there is always the uncertainty in regard to future development which may make necessary radical changes in the distribution of the loads. For this reason the mat foundation which insures equal settlement and at the same time permits any desired shifting of the loads is the one most suitable for a power plant. In this latter method the area of the site is filled with piles at practically uniform spacing, and these capped with a monolithic mass of concrete.

The erection of a central station or a power plant is a branch quite different from the design. The engineer in charge of the design must possess knowledge of how certain machines are assembled and how the various parts of a machine are handled during the process of erection. This knowledge will enable him to allow for proper size openings in walls through which various parts must be taken. He must also know where to allow for his last piece of pipe to complete the pipe lines. These are but a few examples of many that an engineer will find himself up against during the design of a complete plant.

After the plans are complete in that all the machinery is permanently placed and all the pipe lines, valves, fittings, etc., are located, they must be carefully checked and dimensioned. In checking the various pipe lines it is not only necesesary to check the dimensions, but lines must be carefully checked to see that ample provision has been made for supporting them, and that proper allowance has been made for expansion. In the pipe layout it is of the utmost importance to constantly bear in mind the flexibility of the plant in case of a breakdown of a certain unit or any part thereof.

The next in order is to make out a list of the material necessary for the complete piping system. While this may seem at first sight to be a tedious job, it can best be accomplished by first securing a comprehensive idea of what is required, and then by keeping in mind what purpose the bill of material is to serve. If it is merely to serve as a bill of material from which to make up the various pieces in the shop, or if it is to serve as a guide for the men on the erection, will determine how it shall be made up. Often it is necessary that it serve for both the men in the shop and the men in the field.

A system not altogether new but which has given perfect satisfaction where used on a number of jobs to the writer's knowledge, is given herewith. The various pipe lines are numbered in such a manner that each piece as made up in the shop bears a number. This number is placed inside a heavy circle placed tangent to the side of the pipe fitting or valve, as the case may seem best. These numbers have a letter prefix which indicates whether the particular piece of pipe is a steam, exhaust, or water pipe. Such pipes are marked with respective prefixes and numbers, as S 20, E 14, or W 33. On the bill of material these marks are placed with the particular piece under the proper list and in such a manner that all steam pipes, valves and fittings are listed together, likewise all exhaust pipes and fittings. Where this has been done all of the various lines are made up in groups. By numbering each piece consecutively this system can be made up in such a way that by means of an index in connection with the bill of material one can easily find the item number for any particular piece in any particular pipe line. These marks are printed on the various pieces, after they have been tested and before leaving the shop, in white paint. Thus one is able to locate a piece of pipe or fitting on the plans. By referring to the index we obtain the page numbers with item numbers, and finally the mark that the particular piece of pipe will bear. Likewise upon looking at a piece of pipe and noting the mark, one is able to tell at an instant whether the piece in question is a steam, exhaust or some other pipe. Then again by following a route in affixing these numbers to the pipes the system becomes more valuable both in locating material and also as a guide in referring the home office to the pipe or fitting that is in question. Furthermore, it serves as a protection in placing the fitting where it is intended to go.

This system has been worked out so thoroughly that it was possible to ship complete material for a central station from a most northerly point of the U. S. to Mexico, and there erect a complete plant with but two or three very light shipments during its construction. This particular plant consisted of six B. & W. boilers set in three batteries, four cross compound condensing engines directly connected to alternators, independent jet condensers, low service pumps and boiler feed pumps, feed water heater, and the necessary pipe to complete the plant for operation.

MECHANICAL REFRIGERATION.†

By E. E. MAHER.*

In the transfer of a solid into a liquid, or a liquid into a vapor, a certain amount of heat is required to accomplish the transformation. The heat employed in making these changes becomes latent and the quantity of heat so employed must be removed in active form before the transformation is accomplished. It is upon this physical law that the science of refrigeration is based.

The transfer of heat from one body to another, or the law of thermodynamics, must be understood in the study of this subject, as it is by the application of this law that we are able to accomplish by mechanical means the refrigerating effect necessary to the production of cold, which is the absence of heat.

The demands of civilization, whenever they become sufficiently insistent or essential to our further development, are always met by corresponding advances in science. It has always been so and will continue, until we have forced from Nature her last, most deeply hidden secret.

In the development of the science of refrigeration, we have progressed slowly, and while we have accomplished much, we are still far from having reached that point of achievement which justifies any great degree of complacency. We may reasonably expect future accomplishment to show our present methods to be crude, indirect and extravagant to a degree. This particular branch of engineering undoubtedly offers an attractive field for endeavor. For the ambitious who are prepared and willing to accept Nature's challenge and make the sacrifice which she requires always as the price of success, the prize is waiting.

The ancients in warm climates cooled their drinking water by swinging it rapidly in the open air in open vessels, or in skins, which were then used quite generally as containers. In this way a portion of the heat was absorbed by the air, causing a fairly rapid evaporation, which resulted in reducing the temperature of the water.

In Eastern countries, even today, methods almost as primitive are employed. In Northern India ice is produced in

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†For the data regarding the history and development of mechanical refrigeration, the writer is indebted to Mr. Edwin S. Shepard, Consulting Engineer, and to "ICE AND REFRIGERATION" for the tables given.

*Formerly of Class of 1905. Secretary, the B. M. Osbun Co., Mechanical Equipment, Chicago.

small vessels wrapped in damp cloths and placed in a position where a strong current of air will strike it, thus causing rapid evaporation, a process in which heat is absorbed from the water with a resulting lowering in temperature sufficiently to cause thin crusts of ice to be formed.

Early in the sixteenth century an Italian chemist produced a reduction in temperature by dissolving saltpetre in water. This was the first recorded successful assault by science on Nature's thermal citadel. A few years later another chemist succeeded in developing still lower temperatures by the use of various combinations of chemicals such as nitrate of ammonia, sulphuric acid, muriatic acid, etc.

The first successful application of machinery to the production of cold, was by one "Vallance" in 1824. This gentleman constructed an apparatus by which air was circulated over vats of sulphuric acid. In this process the acid absorbed the moisture from the air and thereby caused it to become highly rarified. The rarified air was then circulated over pans containing water, during which procedure the air absorbed the heat from the water, reducing the temperature proportionately. By a crude arrangement the process was made continuous.

During the period from 1824 until about 1870 many and various attempts were made to produce refrigeration by mechanical processes. Many attempted to accomplish the desired results by compressing air and permitting it afterward to expand, but this method was found impractical after many attempts, on account of the large volume of air necessary to be handled and the difficulty of producing machinery that would do this work practically.

About the year 1870 a machine was brought out in America with which cold was produced by the evaporation of ether. The ether was vaporized in a series of coils or in a closed vessel connected with a pump, which on its return stroke compressed the ether and discharged it into another series of coils submerged in water, which in turn absorbed from the ether the heat it had taken up during the process of vaporization. This resulted in the ether being again liquified and made available for further use.

Thus was established the first compression system, which has since become the recognized method, and the cycle of operation then employed is still the accepted principle of all compression systems, and is the most practical known method of transferring heat by mechanical means.

Many and costly experiments have been made, during which many refrigerating agents have been tried: ammonia, sulphurous oxide, carbonic acid, nitrous oxide, cymogene and other chemical compounds, until by experiment it was found that ammonia, when dehydrated, adapted itself most readily to the requirements on account of its extremely volatile characteristic and its disposition to vaporize at temperatures (when pure) as low as —28 3/16° Fahr. at atmospheric pressure.

Ammonia is a combination of two gases: nitrogen and hydrogen, and takes the chemical symbol NH_3. Pure ammonia is colorless and alkaline, and its latent heat is greater than that of any other known agent. Its permanence, its character of not being inflammable or explosive, and the readiness with which it can be produced has resulted in establishing anhydrous ammonia as the chosen refrigerating agent.

Compared with water, its specific gravity at 32° Fahr. is about 0.6364. One cubic foot of liquid ammonia weighs 39.73 pounds. Its specific heat is 0.50836; its latent heat of evaporation is approximately 560 B.T.U. When fully evaporated, the volume of one cubic foot of liquid becomes 21.017 cubic feet.

From what has been said, the reader will understand that in the employment of anhydrous ammonia as a refrigerating agent, the heat is absorbed from surrounding substances, such as air, water, etc., by the ammonia. In its practical application it becomes necessary to confine the ammonia so that it cannot escape, in order that it may be used again, otherwise the expense of mechanical refrigeration would be prohibitive. This condition makes it necessary to employ closed vessels in which the ammonia may be expanded or vaporized and other closed vessels in which it may be condensed or reliquified . For this purpose pipe coils are generally used, the liquid ammonia being admitted to the evaporating coil by a regulating valve, and the coil placed in the room to be refrigerated, or submerged in the liquid to be cooled. Coming in contact with the warm surfaces, the ammonia immediately commences to absorb heat, which causes it to vaporize and expand in the coil. At this point it becomes necessary to remove the vapor from the coil, this being done by means of a pump, which, like any other pump, creates a vacuum into which the vapor flows until it reaches the pump piston. Here, by a valve arrangement, it is admitted past the piston, which upon its return stroke, compresses the gas into a comparatively small space, thereby rapidly increasing its temperature. In this condition it is discharged from the pump cylinder into another

coil, which is either submerged in cold water or arranged so that the water will flow over the outside, or so that the water in some manner will come in direct contact with the outside of the pipe in which the ammonia gas is held. Here the heat of compression which had previously been absorbed by the ammonia in the process of expansion is absorbed by the water so that the ammonia again becomes liquid, ready for further service.

It will thus be seen that in the last analysis, the refrigeration is accomplished by the water during the process of condensing, and the importance of the water supply becomes ap-

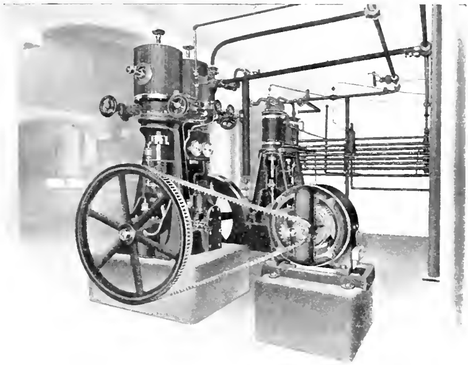

Fig. 1. Motor-Driven Single Acting Refrigerating Machine.

parent. Upon the volume of water available and its temperature, the whole practicability of a refrigerating or ice making plant depends.

Several different types of pumps and coils have been designed for circulating ammonia gas, which on account of its extremely volatile character is difficult to confine, and so it is necessary in the building of these pumps and coils to exercise great care to provide strong, closely fitting parts.

Among the first to recognize the commercial possibilities of mechanical refrigeration and to engage in the manufacture of special machinery and equipment for its production, was David Boyle, a very practical machinist with an inventive mind, who, about the year 1870, designed and built the first

practical commercial refrigerating machine; afterward establishing in Chicago what came to be a very large industry.

The Boyle machine, or pump, was of the vertical or upright type with duplex, single acting cylinders operated by a reciprocating engine. These machines were exceptionally successful, and many of them are in use today, still performing splendid service, which is indisputable evidence of the excellence of their design and construction. Other manufacturers came into existence with the growing demand for refrigerating machines, all adopting the general principles and design of the Boyle machine, that is: the vertical single acting type with duplex cylinders, and for many years this was the only type of ammonia pump in use. Later, however, with the development of the spirit of commercialism, there came others who sought to build their fortunes by adopting a different design—one that would be cheaper to manufacture; and we now find ourselves introduced to the horizontal double acting type of pump, in which but one cylinder is employed, with the compression at both ends. The lower price made possible by this design attracted many purchasers, and the business flourished. The newer, cheaper design of pump challenged the older on the ground of cost and won many victories on this ground alone. Some among the original manufacturers of vertical machines abandoning their ideals, adopted the newer design, hoping thereby to secure some financial gain for themselves. Others held steadfast to the original and sought by improved manufacturing methods and by a consistent regard for their obligation to the public, to maintain their position in the trade, and it is significant that they have been successful—signally so.

With the advent of the horizontal, double acting machine, many builders and manufacturers, who were at that time engaged in the manufacture of other lines of machinery, with little knowledge of the principles of engineering involved, and with no adequate conception of the requirements of the refrigerating machine business, engaged in their manufacture, attracted by the lure of gain; and it came to pass that there were nearly as many manufacturers as purchasers, which occasioned much strife (not all have survived).

Meantime, new uses had been found for refrigerating machinery and the demand increased, and is still increasing, until now there is scarcely a department of manufacture or production in which refrigerating machinery may not be employed to advantage.

During the period since the horizontal type of pump has

been on the market, there has been much discussion and no little controversy between these manufacturers and the manufacturers of the single acting type concerning the relative merit of the two.

For a long time, the engineering profession was confused by the multiplicity of conflicting claims that could not be proven because sufficient time had not elapsed to develop or disclose the inherent weakness of the horizontal double

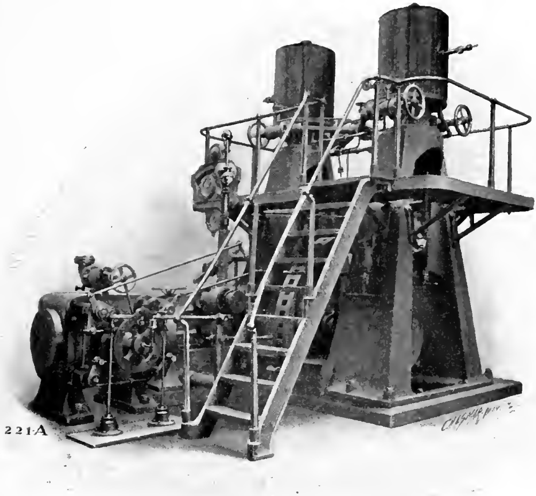

Fig. 2. Engine-Driven Single Acting Refrigerating Machine.

acting pump, although its defects had been determined theoretically by those of the profession who had given the subject intelligent and conscientious study.

Now, however, with the aid of critical tests made possible by the application of improved appliances and methods of testing, aided also by a clearer understanding of the principles involved and their application, we have had proven for us beyond question that the original design—that of the vertical single acting pump, in which compression is at one end of the cylinder only, is far, very far superior to the horizontal double acting type.

During the past two years one of the large manufacturers of refrigerating machinery has made a series of exhaustive tests to determine the relative efficiency of the two types of pumps. These tests show a greater clearance loss as well as a loss in power required in the horizontal double acting machine, as will be noted in the detailed record of these tests herein given:

Series XXV. Runs 461 to 479; 12½"x18" single acting machine, 70 R. P. M., 185 lbs. gauge condensing pressure; 95.5° F. Liquid at expansion valve.

Gauge Pressure in Suction Pipe (by Mercury Column)	Linear Clearance Inch	Clearance Volume in % of displacement	Discharge Temperature Degrees F.	Ton by Ammonia	Compressor I. H. P. per Ton
5 lbs.	1/32	0 24	251	22.7	1.75
5 lbs.	1/8	0.76	251	22.6	1.77
5 lbs.	1/4	1.46	242	21.0	1.81
5 lbs.	1/2	2.85	245	19.7	1.82
5 lbs.	1	5.63	230	15.5	1.83
16.57 lbs.	1/32	0.24	230	38.0	1.30
16.57 lbs.	1/8	0.76	233	37.2	1.32
16.57 lbs.	1/4	1.46	232	35.6	1.34
16.57 lbs.	1/2	2.85	230	34.4	1.36
16.57 lbs.	1	5.63	223	29.7	1.39
25 lbs.	1/32	0.24	213	50.4	1.09
25 lbs.	1/8	0.76	212	50.1	1.10
25 lbs.	1/4	1.46	214	49.1	1.11
25 lbs.	1/2	2.85	212	47.0	1.12
25 lbs.	1	5.63	209	42.6	1.13

Series XXVI. Runs 480 to 498. 12½"x18" double acting compressor, 70 R. P. M., 185 lbs. gauge condensing pressure; 95.5° F. Liquid at expansion valve.

5 lbs.	3/64	0.42	321	19.2	2.18
5 lbs	1/8	0.85	338	17.3	2.34
5 lbs.	1/4	1.55	335	16.0	2.45
5 lbs.	1/2	2.93	341	14.3	2.56
5 lbs.	1	5.71	329	10.6	2.89
16.57 lbs.	3/64	0.42	287	33.0	1.60
16.57 lbs.	1/8	0.85	292	32.1	1.62

16.57 lbs.	1/4	1.55	285	30.0	1.64
16.57 lbs.	1/2	2.93	293	28.9	1.72
16.57 lbs.	1	5.71	300	22.9	2.01
25 lbs.	3/64	0.42	253	47.4	1.26
25 lbs.	1/8	0.85	259	45.1	1.28
25 lbs.	1/4	1.55	255	44.8	1.30
25 lbs.	1/2	2.93	261	42.3	1.35
25 lbs.	1	5.71	265	36.5	1.44

Series XXV and XXVI. Runs 461 to 498. Single acting vs. Double acting compressors. Compressor I. H. P. per ton.

Linear Clearance Inch	Clearance Volume in % of displacement		5 lbs. Suction pressure		16.57 lbs. Suction pressure		25 lbs. Suction pressure	
	S.A	D.A.	S.A.	D.A.	S.A.	D.A.	S.A.	D.A.
1/32	0.24	....	1.75	....	1.30	....	1.09	....
3/64	....	0.42	....	2.18	....	1.60	....	1.26
1/8	0.76	0.85	1.77	2.34	1.32	1.62	1.10	1.28
1/2	2.85	2.93	1.82	2.56	1.36	1.72	1.12	1.35
1/4	1.46	1.55	1.81	2.45	1.34	1.64	1.11	1.30
1	5.63	5.71	1.83	2.89	1.39	2.01	1.13	1.44

Series XXV and XXVI. Runs 461 to 498. Single acting vs. double acting compressor. Tonnage per 24 hours.

1/32	0.24	....	22.7	....	38.0	....	50.4	....
3/64	....	0.42	....	19.2	....	33.0	....	47.4
1/8	0.76	0.85	22.6	17.3	37.2	32.1	50.1	45.1
1/4	1.46	1.55	21.0	16.0	35.6	30.0	49.1	44.8
1/2	2.85	2.93	19.7	14.3	34.4	28.9	47.0	42.3
1	5.63	5.71	15.5	10.6	29.7	22.9	42.6	36.5

Concerning these tests, it is well to observe that they were made with new and perfectly fitted pumps. A little reflection makes it clear that in practical use the wear on the horizontal type of pump will be much greater than on the vertical type. The heavy piston, wearing on the bottom of the horizontal cylinder soon develops a leak on the upper side, causing a loss of efficiency which increases in proportion to the length of service. At the same time, this wear on the bottom of the cylinder tends to throw the piston rod out of line, so that the wear and friction on the stuffing box is greatly increased, thus calling for a corresponding increase in power

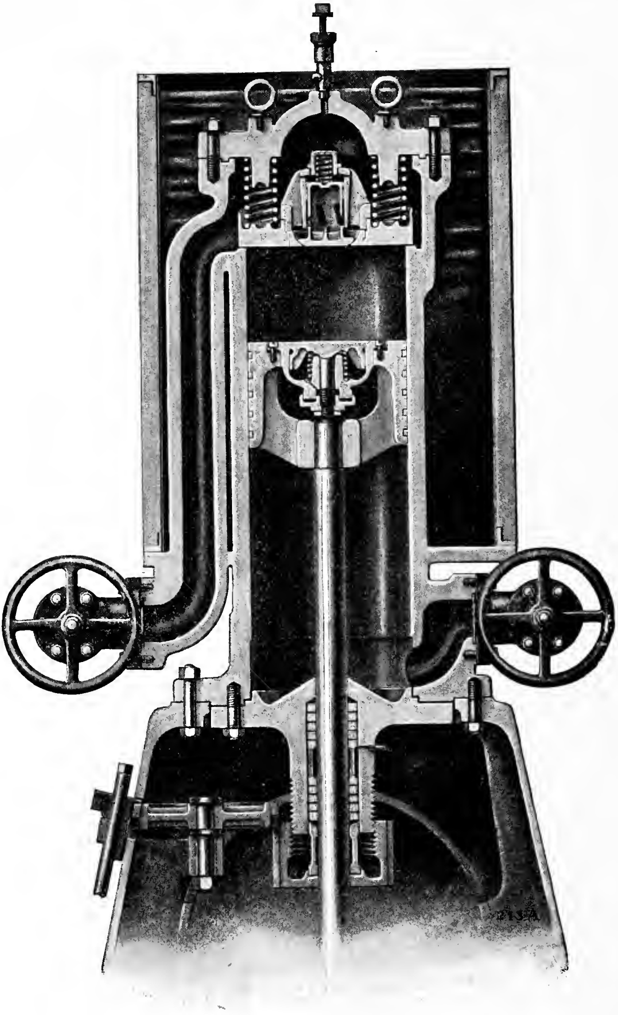

Fig. 3. Cylinder of Single Acting Refrigerating Machine.

required. With the vertical type of machine, the pistons are perfectly balanced on the cross head and there is little perceptible, and no unequal, wear on the cylinders, which makes it apparent that the advantage shown in favor of the vertical type of pump in the above tests grows more pronounced in proportion to the length of time that the machines are in service.

The manufacturers of vertical machines have always contended that it was impractical to compress an elastic gas against the stuffing box and their contention seems to have been proven in the above tests.

About this time the situation was further aggravated by the fact that the many builders of horizontal pumps, striving amongst themselves, sought to meet competition and overcome it by cutting down their manufacturing costs. This resulted in cutting out material wherever possible, at the same time increasing stresses by increasing speeds, all with a reckless disregard for the factor of safety, and encouraged always by the indiscriminating and misinformed buying public, with its exaggerated ideas of the value of money and a child-like disregard for the element of hazard.

The laws of physics cannot prudently be disregarded nor can Nature be outraged with impunity. The inevitable happened. We commenced to hear of accidents—ammonia explosions (which were never explosions, but defects in design and construction resulting in fracture and flooding of ammonia). Many lives of innocent victims—sometimes a dozen or more at a time—were thus sacrificed to ignorance and greed. It is not easy to determine which is the more culpable: the purchaser with his exaggerated estimate of dollars, or the manufacturer whose greed for gain caused him to disregard his responsibility to society.

Reviewing the past two decades, we are compelled to recognize the fact that much that has been classed as progress in the development of the science of mechanical refrigeration is negative progress; essential perhaps in the process of evolution, but not pleasant to review.

It is interesting to know, and a fact that may be reflected upon with profit, that the one company which has been most successful financially and which now enjoys the most enviable reputation among the engineering fraternity is the one and only company which has adhered strictly to the vertical single acting type of pump and has refused to abandon its ideals for temporary pecuniary advantage; while most of those which were attracted by the lure of gain and which engaged in the

manufacture of the cheaper type of pump have generally reaped bitter disappointment. A few have achieved temporary financial success in a very moderate degree, but their future is not bright, nor can their past record be a source of very general satisfaction.

The lines of divergence are becoming more clearly defined, the interested public are thereby enabled to gain a clearer understanding of the subject, and are coming to exercise a greater discrimination in the purchase of their equipment, all of which is most encouraging to those who are conscientious in their endeavor and who believe in the ultimate success of conscientious effort.

Until within the past two years there has been little change and no material improvement in the method of circulating and expanding ammonia or in the method of condensing. The most notable departure from the original is a method perfected and adopted by the Frick Company of Waynesboro, Pa., one of the oldest and best known manufacturers of refrigerating machinery. We refer to what they call their "flooded system."

The original method consisted in admitting a spray of liquid ammonia into the expansion coil through a needle-pointed valve which graduated the quantity of liquid according to the operating conditions. In practice it has always been found difficult to regulate the quantity of liquid admitted owing to the varying conditions and changes in temperature experienced in a refrigerating plant in operation, and much annoyance and loss of efficiency has resulted on this account.

With the Frick Flooded System, the liquid ammonia is admitted in a body into the expansion coils, and by an ingenious arrangement is held in the coils until it becomes fully vaporized. This method results in supplying to the coils the maximum amount of ammonia that can be vaporized at all times and under all conditions, and makes unnecessary the close regulation and continual readjustment required in the old system. In practice it is found that the efficiency of the cooling surface represented by expansion coils is increased from 25% to 33 1/3 % with the application of this improved method.

The scope of this article will not permit of a detailed explanation of the many and varied applications of mechanical refrigeration as employed in the various departments of manufacture and production in which it has proven practical.

In the manufacture of ice, the cooling of rooms in which provisions are stored, sometimes for months; in the re-hydrating of air used by steel mills in blast furnaces for the manufac-

ture of steel billets; in the manufacture of agricultural implements; in the chilling of iron; in horticulture—for the preservation of flowers, bulbs and fruits; in the transportation of tropical fruits in vessels and cars by means of which ripening is retarded so that the fruit does not become over-ripe or decayed in transit; for the freezing of fish and other sea foods; in the manufacture of explosives for reducing the temperature of the chemicals during the mixing process by which the danger of premature explosion is eliminated; in heavy construction work where quicksand is encountered in tunnelling or sinking shafts, or in laying foundations, freezing the quicksand so that it may be taken out in solid blocks; in surgery and medicine; in the pasteurizing of milk and other food products; in the preservation of valuable furs; in the manufacture of films used for photography; in the manufacture of glue and soap; and in the process of refining petroleum. All of these processes are intensely interesting to the student of engineering and offer the widest possible opportunity for the exercise of ingenuity, since every refrigeration installation requires a different arrangement and a different readjustment of proportions to suit the local conditions and meet the requirements of the particular duty demanded.

In the installations of the last twenty years or more the writer does not know of two ice plants or two refrigerating plants that are exactly alike in every detail. Some new condition or combination is always present in each individual installation, presenting new problems to be worked out and offering unlimited opportunity and encouragement to the engineer for the exercise of all of his natural ingenuity and for all the knowledge and wisdom that he may have acquired.

If we have succeeded in making clear the fundamental principles upon which the science of refrigeration is based, and if in reviewing the history of its industrial development, in which we have pointed to the mistakes that have been made; we have warned any who may come after us, then we have accomplished our purpose. At the same time, we shall be gratified if we have inspired in the minds of any of the coming generation of engineers that respect for high ideals, and that confidence in ultimate success of those, who having high ideals adhere to them, and consistently refuse to offer to the world anything less than the very best of which they are capable, always striving toward perfection, thus realizing life's purpose and its grand possibilities.

THE McMULLEN PROCESS FOR SUGAR MANUFACTURE

By HARRY McCORMACK, M. S.*

The development of any new process based on chemical principles will occur in the way of, first, the idea, the experimental or laboratory period, then the factory or commercial period. Having been rather closely identified with the development of this process, perhaps I can trace all the steps in the evolution of this method of sugar manufacture.

Mr. McMullen and his associates had been working for a number of years on a method for drying sugar beets and extracting the sugar from them at any convenient time. This had been brought to a successful termination in the laboratory, when one day Mr. McMullen came to me saying that he believed the sugar cane offered a greater field for the application of the new process, than did the sugar beet. We discussed the question for some time, and went over the available literature on the subject of cane composition, cane and sugar yields per acre in various countries, and losses in the present processes, which we deemed would be avoided in the new process.

Yields of Cane and Sugar in Various Localities.

Locality	Tons Cane per acre.	Tons sugar per acre.	Pounds Cane per lb. Sugar.
Barbados......	36	2.90	12.4
Louisiana......	26	2.49	11.8
Mauritius.. ...		2.25	
Queensland....		2.30	
Sandwich Is....		2.43	
Same irrigated		6.11	

As we looked into the subject, we noted the high sugar content of the tropical cane as compared with the sugar beet: we noted the amount of cellulose present in the cane which would be available for the cellulose industries as soon as the sugar had been **completely** extracted, and also thought we saw how cane sugar could be made without a refinery.

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Average Composition of Cane.

Water	71.04 per cent
Sugar	18.02 per cent
Cellulose	9.56 per cent.
Albuminous	0.55 per cent.
Fatty and Coloring	0.35 per cent.
Mineral matter	0.48 per cent.

We found in the literature descriptions of previous attempts to extract the sugar from cane by diffusion, and while these attempts had not gone to successful commercial termination, we could not see anything very discouraging in the accounts given.

Newlands, in his Handbook on Sugar, gives the following historical accounts of diffusion processes as applied to the cane:

"Although borrowed from the earliest stage of the beetroot industry, it was not till 1843 that the operation of slicing was applied to the sugar-cane. It was hoped that the cane, after having been sliced, dried, and ground to powder, might be preserved long enough unchanged in this condition to allow of its being transported to Europe, where not merely the whole sugar might be extracted at once in its purest form, but the ligneous portion would furnish an inexhaustible supply of fibre for the paper market. The dried cane powder, however, became altered on the voyage, and not only did great part of the sugar disappear, but the changes consequent on its decomposition discoloured the residuary fibre. But there was one result from this trial sufficiently noteworthy. It was clear that the cane could be sliced and dried in commercial quantities, and several of those concerned in the matter determined to extract the sugar on the spot; accordingly, more than one attempt was made to carry out the slicing, and apparently every obstacle was overcome, when the building erected for the plant, was, unfortunately, burned.

One of the principal difficulties hitherto had been that of drying the sliced cane; to avoid this, in 1845 Constable and Michel introduced their method on the estate of Ste. Marie, the property of Major Bouscaren, in Guadeloupe. It was as follows: The canes which were sliced at the rate of 1 ton in twenty minutes, fell into metallic baskets, each capable of holding that amount. The baskets were moved by a central

crane, and around the crane, at equal distances, were placed 6 copper vessels, adjusted to receive the baskets when filled. These copper vessels were filled to such an extent with water that when the basket, full of sliced canes, was lowered into any one, the liquid rose to the surface. The basket No. 1, with its contents, having been thus dipped into vessel No. 1, was allowed to remain immersed till such time as the sliced canes had parted (by displacement) with a due proportion of their sugar to the water in vessel No. 1; basket No. 1 was then hoisted out by the crane, and consigned to vessel No. 2, where a second proportion of sugar was displaced; and so on throughout the series. In the meantime, a fresh basket full of sliced cane was consigned to No. 1 vessel, the liquid in which extracted a further proportion of sugar, and so on, till the contents of the first vessel were as fully saturated with sugar as the law of displacement allowed and the slices of cane in the first basket were proportionately exhausted.

This was virtually the old system of Dubrunfaut with its defects, viz., that the water was not easily kept at a suitable temperature; that the whole sugar was not extracted; and that, from the time which elapsed between slicing and exhaustion, considerable changes occurred in the saccharine fluid, which affected the quantity and quality of the result. These defects in principle did not, however, of themselves contribute much to the failure of the plan; the system broke down in the subsequent evaporation, in which the heat employed was generated entirely from gas manufactured on the spot—an operation attended with such difficulties, that the trials were given up after heavy outlay. This was much to be regretted, as the slicing process had shown that a much larger proportion of the sugar could be extracted from the cane than had been hitherto done in any other way.

A system so simple and yet promising such complete results was not destined to disappear without leaving traces. In Sept., 1847, Davier, apothecary-in-chief to the French service at Basseterre, resumed the experiments of slicing and drying the canes, at the point where they had left off in 1845. He found that by driving off about 33 per cent of moisture from sliced canes they became so friable as to be reduced, without difficulty, to a coarse powder in which the colouring matter and albumenoid principles of the cane had become insoluble in water, while the saccharine elements were crystalized unchanged and ready for immediate solution and extraction by

either hot or cold water. The former would have been the more rapid, but he met with an objection to its use, which, if not scientific, was at least practical. The vessels he employed were of copper, and transmitted heat so rapidly that the attendants were constantly burning their fingers; he did not consider it worth while to take any precautions to avoid this evil, as he found cold water sufficient for this purpose, and more economical. The process he adopted was the following: Six upright cylinders of copper, about 4 ft. high and 9 inches in diameter, were so arranged as to communicate with each other, and with a reservoir of water on a higher level; they were each furnished with gauges and stopcocks; five of these were filled with cane powder, and the last with animal charcoal—this was merely precautionary, but not essential to the work. Water was admitted into No. 1, and retained there for twenty minutes after the gauge showed that the vessel was full; it was then passed into No. 2, and so on. In practice, it was found that, on escaping from No. 4, the water had absorbed so much sugar as to mark 22.5°B., or about the density when syrup is usually consigned to the vacuum-pan; and that the cane powder first in contact with the water, viz., that in No. 1, was completely exhausted, even to the taste, that most convenient and reliable saccharometer, and represented what it was reduced to in reality—a mass of wet sawdust. At this stage of the process, it was removed from No. 1, and replaced by a fresh portion of cane powder. As this part of the operation was performed without interrupting the duties of the other cylinders, it is clear that two of the greatest desiderata had been attained, namely, the complete extraction of the sugar in a state of purity, and that by a continuous operation.

The mechanism thus employed by Davier in September 1847 appeared to leave little room for improvement. It was submitted to, and approved by the French government, who commissioned the inventor to repair to Paris in the ensuing month of March to take the necessary steps for erecting a set of machinery on a larger scale on the French King's estate of Tremoiullant, in Martinique. Fortune seemed about to crown Daviers laborious and successful trials, when the French Revolution intervened and the new process was shelved.

Since that date, the Hon. H. S. Mitchell, has several times, in conjunction with H. Warner, repeated the process of slicing and drying the sugar-cane, with exactly similar results, namely, the extraction of all the contained sugar by displacement

with cold water in about 1 hour and 20 minutes, in the form of a pure syrup, marking between 22° and 23° B.

Warner next directed his attention to the slicing of the cane, to ascertain how far he could succeed in extracting the sugar without recourse to drying the slices. After repeated trials, conducted with every precaution, he succeeded in obtaining, by displacement, a liquor marking 9°B. This was a great success, but not equal in results to the mode where the slices were dried,because there was not only an original loss in obtaining the whole sugar, but the juice had an opportunity of becoming changed to an extent that greatly increased the quantity of uncrystallisable sugar. This latter evil was mitigated by the use of small doses of antiseptics in the displacing water, so as to preserve the juice unchanged throughout the process of manufacture."

Newlands also describes some later experiments on diffusion processes in which the object is to enrich the juices obtained in crushing by passing them through a diffusion battery containing fresh crushed cane. He dismisses the subject of diffusion, however, with the statement:

"Looked at simply as a process for extracting a large percentage of sugar from the cane, diffusion is beyond question, a great success, but most planters are more anxious to make money than to make sugar, and consequenntly, the whole matter depends on the question—will it pay? This in turn, hinges almost entirely on the question of fuel."

We thought however, that the question of fuel was not the paramount one, as it seemed very poor economy to use cellulose, valued certainly at one cent a pound, for fuel, when its cash value as fuel is about $1.25 per ton, with coal at the price it brings in Cuba.

We note in the earlier experiments some points indicating the advantage of treating the cane in some such way. For example, the experiments of Davier, made in 1847 showed that cane could be dried without material change in its sugar content; that the powdered dry cane could be made sugar-less in six changes of water; that the juice had a high purity, and that its sugar content was satisfactorily high.

It is striking that the literature of sugar should contain an account of such a process, for nearly sixty years without other attempts being made to bring it to a satisfactory conclusion. And during all this time, there were no changes of any revolutionary character in the industry. It is true that in the cane sugar industry there was considerable progress in the

mechanical equipment of a sugar mill, and that the cost of refining raw sugar, has been decreased a few fractions of a cent, but the mills and factories were yet idle forty percent of the time, and all the cane sugar was marketed as raw sugar having yet to be subjected to refining.

Our first experimental work was done on fifty pounds of cane secured from Mexico, and which was about three weeks on the road, consequently not arriving in the best of condition. At this time, too, we had no satisfactory method of shredding the cane; the first lot was chipped up by fastening it in a carpenter's vise, and shaving it with a draw knife. Our work showed us at once, however, that the cane could be satisfactorily dried, and that we could get a rich and pure sugar juice from it, provided the sugar content of the cane was right when we started with it. In other words we proved that the dried cane could be prepared with its sugar content unchanged by the drying operation.

We next went on a search for a satisfactory cane shredder, and found one being operated on the Louisiana plantation of Ex-Gov. Warmouth, shredding the cane for the only cane factory where the diffusion process is in use. A small machine of this type was built; the drier which we had been using on beets, was brought to Chicago, and thirty tons of Louisiana cane were secured for the drying experiment. Enough cane was dried to enable us to make an estimate on the cost of drying, and to supply us with sufficient material for diffusion to obtain the sugar juices, and the exhausted material for paper stock.

Our results were not always just as we would have liked, but they were of such a nature as to convince us that the process would be a commercial success. The sugar juices were of higher purity than those we could obtain directly from the cane, the diffusion could be so regulated as to give us a sugar juice of any concentration desired, and the exhausted cane made excellent paper.

We then thought that our results justified work on a commercial scale, so a site was secured on a large Cuban plantation and a factory built to dry 500 tons of cane per day.

The operation of this plant will be described. The cane comes from the field to the factory on flat cars, and is transferred from the cars directly to the runway of the shredder. The shredder consists of a toothed cylinder about 8 feet long, the cane being fed to it by a star feed. The cane passing

through the shredder is cut up into particles about like fine excelsior, falls on a belt and is carried up to the hopper of the drier. The shredded material is fed from the hopper over a hollow steam heated roller, and goes on to the first belt of the drier, at a temperature of about 98° C.

The drier consists of twenty belts, 50 feet long and 12 feet wide, one over the other, moving in opposite directions, and the material falling from the upper one to the one next below. Steam heating pipes are placed between the upper and lower portions of each belt, and an air current, maintained by a suction fan, is circulated by means of baffle boards, across each belt.

The temperature from belt to belt is gradually lowered, as the moisture content of the cane lowers, so that the final drying is done at a temperature of about 85° C.

We formerly had the idea that all the drying must be done with the air temperature under the boiling point of water; this was proved erroneous by sending some wet cane through a direct heat drier with a flame temperature of 1100° C. We still think however that the final drying must be done at a low temperature.

The cane goes in with a moisture content of about 70 and comes out with about 1. The cost of drying has been about $1.10 per ton. The dried material is screened to separate cane fibre from cane pith, and the separated products go to the baling presses to be prepared for shipment.

The products undergo this primary separation on account of their properties. The paper makers had considerable trouble in the past because the two materials behave so differently on cooking. The fibre can now be used alone, making a soft white paper, while the pith will find its chief use in the nitro-cellulose industries as it nitrates very readily and washes very satisfactorily.

The cane yields about 33 per cent fibre and about 66 per cent sucrose and 40 per cent cellulose. The pith contains about 57 percent sucrose and 25 percent cellulose. The pith presses so firmly that it will bear transportation any distance without covering; the fibre, however, must be baled like a cotton bale. The products are now loaded on boat, and transported to any convenient factory for the extraction of the sugar. At the factory the bales are broken up, the dry material passed through a mixer, where dilute sugar juice is added until the material is just saturated with water, and

then passed to a continuous centrifuge for the extraction of the sugar. In the front portion of the machine, the concentrated sugar juice is taken off, in the posterior portion the material is sprayed with water, yielding a dilute sugar juice which is employed to moisten fresh cane. The cane coming from the centrifuge is sugarless, yielding no test for sugar with sulphuric acid and B napthol. It is calculated that an individual particle of cane will pass through the centrifuge in 1/100 part of a second. The extracted cane is ready for use in the cellulose industries while the sugar juices are treated about the same as the beet juices are in a beet sugar factory, except that the juices are sent to the triple effect slightly acid instead of slightly alkaline. The saving on evaporation is considerable as we can easily handle a 22° Brix solution from the centrifuge while the juice in the ordinary factory will run from 10 to 12° Brix on the juice from the rolls. The plantation upon which we have our drier secured a yield just under 80 percent of the sugar content of the cane in their mill last year. This was obtained by passing the cane through three sets of three rolls each and macerating with water between the sets of rolls. This meant a sugar loss on this one plantation of 19,000 tons.

I would sum up the advantages of the McMullen process as follows:

(a) Enables the factory to be located where fuel and labor conditions are most satisfactory, and to operate continuously.

(b) Secures all of the sugar from the cane, not eighty percent of it.

(c) Saves about 50 percent of the evaporation cost on the sugar juice.

(d) Makes available for the cellulose industries one half pound of cellulose for every pound of cane sugar made.

(e) Places refined sugar on the market without intervention of a refinery.

We all know that the final test for any new process is "will it pay?" I can best answer this by concluding with a tabulated statement taken from the books of a typical Cuban plantation and their estimate, **not ours**, of the profits accruing from the adoption of the new process.

Report of a Typical Cuban Plantation.

	Actual results in 1910.	Estimate for McMullen process.
633,220 tons cane at factory, @ $2.50 per ton	$1,592,512.81	$1,592,512.81
Expenses connected with mfg. freight, etc.	2,559,475.79	2,480,884.67
Selling expense	58,748.70	108,719.78
Total Cost	$ 4,208,737.30	$4,182,117.26
Yield		
Raw Sugar & Molasses 137,196,740 lbs.& 2,870,334 gals	$5,880,812.74	Refined Sugar 165,488,414 lbs. 8,374,420.70
		Molasses 2,000,000 gals
		125,000,000 lbs. fibre $1,250,000.00
		Total value $9,624,420.70
Profit.	$ 1,672,075.44	$5,442,303.44

Additional profit per ton cane by McMullen Process..$5.95

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EDITORIAL.

In view of the interest and enthusiasm manifested in the meetings of our student engineering societies this past year, we are prompted at this time to add a few words which we trust will stimulate in the minds of the undergraduates a little of the zeal for the work of these organizations that has characterized the meetings of the past year. Obviously it would be difficult in these few lines to dwell on all of the advantages that are to be derived from affiliation with the engineering society in his chosen line of work, but there are a few which are particularly important and which may be profitably considered.

In the change from the theoretical work of the classroom to the more practical work of the profession, the graduate invariably finds himself in a position far removed from that previously conceived. He is apt to find himself in the breach which men of experience tell us exists between college life and practical life, and up against problems which doubtless were never considered in the classroom. While this period for most men is of comparatively short duration, yet it might be further lessened had the graduate been connected with his

engineering society, in which he would have received advice that would have enabled him to better comprehend the actual conditions to be encountered.

In the various meetings at which practising engineers are the speakers, both students and faculty members are kept in touch with present practice and recent developments in engineering work, and become acquainted with modern methods of solving the technical problems of the day. Not only from the actual technical knowledge diffused is the student benefited, but in getting the broader aspect of engineering work at large, thus making him realize that his school training is being conducted along definite and effective lines, and consequently giving him a greater incentive for the work to come. In addition to this—and possibly of more immediate importance to the student—are the words of practical advice coming from these men of recognized standing in the engineering world, advice which does much toward giving him a more adequate conception of the career for which he is preparing.

Another source of development coming to a man through the engineering society is his being assigned an evening on which to lecture regarding some particular phase of work in which he is particularly interested. The confidence inspired, and the help received in the discussions which follow, necessitating a practice of being able to express himself in a clear and forceful manner, are far more advantageous than to be able to make a creditable recitation in the classroom. Moreover, in the reading of a paper and subsequent discussion the listeners as well as speaker are usually found in a more active state of mind than is usually found in the classroom, and so are in a better position to retain any valuable impressions that may be given.

Particularly, however, do we wish to emphasize the help derived from listening to the "heart to heart" talks of the men **who have been there** and **who know**. After having listened to a few of these, as we have had the pleasure of doing in the past year's meetings, the graduate will have that which will serve him well in that trying period just after graduation.

CIVIL ENGINEERING SOCIETY.

On the evening of December 6, 1911, Mr. T. L. Condron, Mem. A. S. C. E., of Condron & Sinks, Civil Engineers, gave an illustrated lecture on "Reinforced Concrete Buildings" before the members of the Civil Engineering Society. Mr. Condron had many excellent slides showing all phases of this class of building work, and in the course of his remarks paid special attention to the layout of plants, and to the best and most economical methods of handling and placing the concrete and steel in the forms. Tests of various methods of floor and column reinforcements were also illustrated and discussed by Mr. Condron.

The meeting on Tuesday evening, February 21, 1911, had for its lecturer Mr. Will P. Blair, Secretary of the National Association of Paving Brick Manufacturers, of Indianapolis, Ind. This Association is engaged in an educational campaign in regard to the use of vitrified brick for paving purposes, Mr. Blair having lectured at many of the western colleges and technical schools along this line. He described and illustrated with stereopticon slides all the processes (both new and old) in connection with the manufacture of brick—especially paving brick. The Association's standard specifications for materials and construction were described. The necessity of a proper foundation was emphasized as well as the selection of a suitable and durable filler—the Association advocating the use of a Portland cement filler instead of a bituminous filler.

On March 7, 1911, the speaker was Mr. Henry R. Matthei, an Armour graduate of the class of 1908. Mr. Matthei, who has been here on a leave of absence from the Philippines, spoke on "Surveying in the Philippines." The methods and procedure of the various government departments, particularly in regard to the extensive surveys now being carried on in the Philippine Islands, were described and discussed.

Mr. John Ericson, City Engineer of Chicago, gave an interesting talk before the Society on the evening of March 21, 1911. Mr. Ericson's talk was truly what he said it would be in his introduction, "a heart-to-heart talk," full of personal experiences, general hints and advice to the young engineer.

On April 4, 1911, Mr. Carpenter, of the Chicago office of the U. S. Reclamation Service, gave an interesting illustrated lecture on the various projects of this part of the Government's work. The lands being reclaimed were described in word and picture both before and after irrigation; the changes accomplished are truly marvelous. Especially interesting were the

descriptions and illustrations of the engineering features in connection with this work.

The last meeting of the year was held on Tuesday evening, April 18, 1911, with Mr. Onward Bates, Mem. A. S. C. E., of Bates & Rogers, Engineers and Contractors, as the speaker. Mr. Bates gave an interesting talk on "The Engineer as a Man." directed mainly to the Seniors about to graduate. Specialization in a particular line that one enjoys or is fitted for was recommended, and several good reasons advanced why this should be done. Two classes of engineers were described, those who make the problems and those who work them out, and "it often takes a better man to make the problems than to work them out." Thoroughness, reliability, good sense and judgment, coupled with engineering knowledge, make the successful engineer. Judgment of men is also a requisite qualification necessary for an engineer, because one cannot always "get men that come up to specifications." The engineer as a lawyer and financier was discussed, and the opinion expressed that the engineer ought to do his own talking, instead of hiring it done; likewise he should finance his work—in other words, be able to start things as well as carry them out." The personal incidents and experiences which Mr. Bates scattered throughout his informal talk illuminated and sent home all the points that were so successfuly made, and created an additional interest as only personal experiences can.

Aside from the regular meeting was held the annual banquet of the Society on Friday evening, March 24, 1911, at the Great Northern Hotel. The dinner was an entire success, and the largest crowd the Society has ever had at such an affair was out. Prof. Phillips presided as master of toasts, and responses were given by Dean Raymond, Prof. Wells, and Prof. Armstrong, by W. A. Kellner of the Alumni, and by Messrs. Jones, Neufeld, and Ford of the student body.

The Society has enjoyed the most prosperous year of its existence, and is now the most active engineering society at the Institute. This is due to the interest taken in the Society by the students themselves and by the civil engineering department's faculty, and it is the hope and wish of the retiring officers and members that the Society may be even more prosperous in the future than it has been in the past year of 1910-1911.

OSCAR R. ERICKSON,
Secretary.

THE CHEMICAL ENGINEERING SOCIETY.

Convincing evidence of the fact that the professional instinct has been instilled in the minds of the students of the Chemical Engineering course is shown in the large attendance and interest exhibited at all the meetings of the society this year.

On February 9th, Prof. McCormack gave a very interesting talk on the subject, "Testing of a Municipal Gas Supply." Prof. McCormack is particularly well qualified to speak on this subject, as he was one of those to figure prominently in the drafting of the new city gas ordinance.

Realizing the necessity of having the social as well as the technical side of the engineer developed, a banquet was held on February 24th at Kuntz-Remmler's, with thirty-one members present.

The next meeting was held on March 2d, at which Prof. McMullen spoke on the subject of "Cellulose." He told of its uses in explosives, paper, artificial silk, celluloid and other products of importance. The talk was followed by a discussion on the structure of the cellulose molecule, a still unsettled question, and some original conceptions were advanced by Prof. Freud.

Quite a diversion was offered on the evening of March 15th, in the way of an illustrated lecture on "The Preparation and Uses of Carbon." The talk was by Mr. Brainerd Dyer of the research laboratory of the National Carbon Company. By means of the slides we were enabled to follow the raw material thru the plant and see it emerge as the finished product. Mr. Dyer had with him a large number of samples showing the various uses to which carbon can be put. Among these may be mentioned electrodes of all shapes and sizes, telephone diaphragms, rheostat plates, arc lamp carbons, dry cells, and graphite crucibles.

Mr. Young, the Chicago manager of the Hoskins Electric Manufacturing Co., has invited the society to the offices of this company, where he will demonstrate the practical uses and operation of electric furnaces.

The final banquet of the year will be held on May 12th. This affair is held primarily for the reunion of the alumni and we trust that the attendance will even exceed the unexpectedly large attendance of last year.

H. SIECK,
Secretary

ARMOUR BRANCH OF THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

The 1911 meetings of the Armour Branch of the A. I. E. E. seem to have surpassed those of any previous year, both in the interest shown in its papers and discussions and in average attendance at meetings. The program followed has been, as usual, to have papers presented by members of the society, by graduate engineers, and by others figuring prominently in the electrical world.

The society was addressed on January 26, 1911, by Mr. T. C. Oenhe, Jr., of the class of '08, on "Automatic and Semi-Automatic Telephony." The data for this paper was taken from the speaker's practical experience in this line of engineering activity, and from this fact he was able to bring to the notice of the society many interesting points not treated in textbooks.

On February 16, 1911, Mr. G. E. Emmons, of the class of 1911, gave a talk on "Frequency Changer Sub-Stations." The data for this talk was drawn from the sub-station of The North Shore Electric Company, situated at Evanston, Ill. In dealing with the subject, Mr. Emmons dwelt on the duties of such a station, and in addition drew out the complete wiring diagram, which he explained in detail. During the discussion which followed, it was brought out that these sub-stations are becoming obsolete in the neighborhood of Chicago, due to the fact that both 25 and 60 cycles per second are being generated by the large companies, and then transmitted to a point of distribution at high voltage, where they are stepped down by means of transformer stations.

At the first regular meeting of March, held on the 2d, Mr. Erick Fenger, Testing Engineer of the Sanitary District of Chicago, presented a paper on "Theory and Engineering in Power Plant Testing." Mr. Fenger outlined briefly the growth in the importance of theory in power plant work as installations become more complex, and described several cases to emphasize this point. In one illustration given, he showed by actual calculation the desirability of having small exciting currents in transformers. Mr. Fenger also gave a mathematical proof of the graphical method of finding the regulation of transformers, a method which is quite simple but not extensively used in this country.

Mr. W. W. Drew, of the class of 1911, addressed the society March 22, 1991, on "Commercial Testing of Small Mo-

tors, and the Retardation Method of Testing." Facts for the first portion of the talk were taken from Mr. Drew's experience while working in Milwaukee; for the second part, from an experiment carried out by the speaker under the direction of Mr. Fenger.

On April 5th, Professor Barrows read a paper on "New Types of Illuminants." Introducing the subject with a short history of the development of illuminants during the last sixty years, giving the date of the first incandescent lamp as 1878 when Swan in England and Edison in this country gave to the public the carbon-filament lamp, he then pointed out the rapid strides in the efficiency of lighting. Prof. Barrows also gave a brief review of the most important types of gas and electric lamps on the market at the present time.

Meetings are scheduled for April 27th, at which time Mr. Tracy W. Simpson, '09, one of the engineering staff of the International Harvester Company, will speak on "Efficiency Engineering."

May 11th, Mr. Frank F. Fowler, consulting engineer, will give a paper on "Engineering Specifications."

J. H. FLETCHER,
Secretary.

MECHANICAL ENGINEERING SOCIETY.

The Armour Student Branch of the American Society of Mechanical Engineers has also enjoyed a most successful year, a success which may be attributed to three sources—the interest taken in the meetings by the upper class men, the help and many valuable suggestions of Professor Gebhardt, and the attendance of the faculty members of the mechanical engineering department. The membership has not been large, yet the average attendance of forty has exceeded the number of enrolled members by fifty per cent.

On February 1st, 1911, Mr. A. H. Anderson delivered an illustrated lecture on "Railway Draft Gears." A good part of the lecture was taken up with a description of the theory of the shock-absorbing parts of the gear. Several curves were shown illustrating clearly the manner in which the shock is taken up and converted into frictional resistance.

At the meeting held March 2nd, Mr. Paul P. Bird, M. E., Chief Smoke Inspector of Chicago, gave a lecture on "The Prevention of Smoke." Mr. Bird during his talk showed

clearly how his department attacked the smoke proposition in and around Chicago. One of the very interesting points brought out during the evening was the subdivision of the steam power plants throughout the city into distinct divisions, based on their order in being smoke offenders against the city.

Mr. W. Sieck, on April 12th, gave an illustrated lecture on "Two Cycle Gas Engines." The advancement made by the two cycle engine from the first successful type down to the present time was brought out, together with the advantages and disadvantages of this type of prime mover over the four stroke cycle engine. The officers for the coming year 1911—1912 were elected at this meeting, the object in so doing being to allow them to become better acquainted with the duties of their new offices.

May 10th the Society will hold an informal dinner and smoker at one of the downtown restaurants, at which all of the members of Society and faculty of mechanical engineering department will attend.

F. H. GRIFFITHS,
Secretary.